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The Latest Application of Blast Furnace Gases in America.

Very striking evidence of the importance of the gas engine in future power development may be found in the announcement in the Current News Supplement of last week that the two new plants of the Universal Portland Cement Co. are to be operated entirely by electric power transmitted from gas-engine generating units located at convenient blast furnaces. As explained last week this company is a new adjunct of the U. S. Steel Corporation, succeeding the Cement Department of the Illinois Steel Co., and utilizes slag in its product, so that the present arrangement is beautifully devised to take advantage of two valuable by-products. Of the two new plants, one with a capacity of 6,000 bbl. a day, will be located at Buffington. In this case the power will be generated at the works of the Illinois Steel Co., in South Chicago and transmitted over the intervening ten miles at 22,000 volts. The second plant will be at Universal, Pa., and will be similarly supplied from the Homestead works of the Carnegie Steel Co., ten miles distant, in each case the generating plant consisting of a pair of 2,000-kw. units. The plan is one that is particularly striking in that the waste gases which it is not always advisable to use on the spot can be fully and profitably employed in this allied industry. The local utilization of blast furnace gases for power is not uncommon and is usually economical, but this extension to subsidiary work at a distance is a very clever move in the direction of saving waste energy. Of course blast furnace gases are not in themselves very desirable fuel for a gas engine; they are not rich enough to work to the best advantage and they are far from uniform. But they would otherwise be wasted and under such circumstances their utilization is almost clear gain. Enough experience has been gained in their use to show that it is feasible in every way and that it pays. From this to the present use is not a very long step, rendered easily practicable by the common ownership of the plants and the existing requirement of slag, which keeps them from being too widely separated.

Cases like these stand quite apart from the general comparison between steam and gas engines, by reason of merely nominal cost of fuel. Yet in the broader case the gas engine has recently been giving very good account of itself. So far as the fuel supply is concerned, a well designed gas engine using producer gas can unquestionably beat out even the best steam engines. owing to far higher thermodynamic efficiency. The points against the gas engine are higher first cost and probably larger depreciation. When producer gas is used the depreciation of the producer also becomes an item of some moment. At the present time no reliable data in these particulars as between steam engine plants and gas engine plants are available. Data there are, but they are vitiated by too large "personal equations." It is astonishing to see how two engineers supposedly competent and honest will take the same case and figure out for it diametrically opposite conclusions in this particular comparison. Yet the great mass of evidence derived from Continental practice is pretty uniformly favorable to the gas plant. Apparently improvements have been pushed much farther there than here, particularly in large units. It is not unlikely, too, that the lower cost of labor abroad may be a factor of considerable importance in this matter, as in many others. A big gas engine undoubtedly requires more attendance than a steam engine of the same power, and in this country such a requirement affects the cost of power far more than it does abroad. And, there being very little experience with big gas engines here to serve as a guide, the instinctive tendency is in the interest of safe conservatism, to over-estimate the unknown quantities, labor and repairs. There is also a tendency to consider producer and boiler-room as being upon much the same basis, which is unfair to the former in virtue of the great importance of gas storage. You cannot run boilers eight hours a day at your convenience and store the steam for use during the other sixteen hours. The plants just now under consideration have the very great advantage of obtaining fuel at nominal cost so that there is every reason to expect high economy in operation. The transmission work is exceedingly simple, so that the cost of power for the cement mills ought to be astonishingly small. With the varied industries which exist in the districts where blast furnaces are common, it should prove feasible to utilize this source of power in many other instances by a relatively short transmission. A waste of energy is as much to regret as a waste of material.

Some Legal Views of Boiler Testing.

The fact that there is a considerable difference between a commercial test of a boiler plant and a warranty test seems to have caused the justices of the U. S. Circuit Court of Appeals, First Circuit, some surprise, to judge from a decision in the case of Arkwright Mills v. Aultman & Taylor Machinery Co., 145 Fed. Rep. 783. No engineer who has had much experience with power plants expects to get as much regular service out of them as the warranty trials develop, although there are a few plants, like the pumping stations of the Metropolitan water-works in and near Boston, which maintain surprisingly good results all the time. As a general rule, however, there is as much difference between a commercial test and a warranty test of a boiler plant as there is between an ordinary road brush between a couple of motor cars and a race between the same machines when they have been stripped, overhauled and put in the charge of the best drivers and machinists. All this is so well known to the engineer as to hardly merit remark were it not for the fact that expensive litigation has recently been conducted which hinges directly on this feature of boiler testing.

The facts of the case seem to be that the defendant agreed to furnish boilers to the plaintiff under the following warranty: "We furthermore guarantee that these boilers will show an evaporation of 10½ lb. of water from and at 212° per pound of dry Pocahontas coal, 1 in. draft, Prof. George H. Barrus to make the test." The boilers were installed and steam turned on them early in 1898. The test was made somewhat more than a year later by the engineer mentioned and showed an evaporation of 9.497 lb.; this test was made after the plaintiff had complained of the efficiency of the plant, and its cost was equally borne by the two parties to the suit. The makers of the boilers contended, however, that it was not a warranty test, showing the best results that could be obtained from the installation, but merely a working test showing what the boilers were doing in regular use, but with the supervision of an expert. On this contention Mr. Barrus testified: "The test which I made was a commercial test to determine the evaporative efficiency of these boilers under commercial conditions. My report states the evaporative efficiency of these boilers under ordinary working conditions." In another part of his testimony he stated that he did not make a guaranty test conforming to the recognized engineering practice in such cases, his testimony reading: "My position is that by tuning the boilers up, by having an expert fireman, and by giving them every advantage, they might be made to evaporate more water than is shown here. I should want, for a guaranty test, an expert fireman." There are a number of points at issue in the case, in addition to those referring directly to the test, but the latter only need be mentioned here.

It will be noticed that thirteen or fourteen months elapsed between the first starting of the boilers and the time of the trial, and it was asserted that this delay worked an injustice to the boiler makers. Uncontradicted testimony was introduced by the plaintiff, however, to the effect that a battery of boilers a year old, if it had been kept in good condition, ought to run a little better than directly after it was set up. Furthermore, the court points out an important fact that is often overlooked by engineers; the purchaser of such a plant has an option, on a breach of the warranty, to return the plant or to retain it and make a claim for damages of the difference between the value of the boilers actually received and the value of the boilers contracted for. It is important to observe this fact, for it is often asserted erroneously in the reports of engineers on the equipment of various plants that there is no further choice left to the prospective purchaser than to accept the plant if up to the requirements or to reject it wholly if below them.

The more interesting question for judicial determination, however, was whether the test made by the expert designated in the contract was a proper test on which to decide whether the boilers had met the guaranty. The court stated that in an ordinary business affair the customary business methods would be considered as binding, but in a technical matter it was entirely rational to expect that a test made under the most favorable conditions would be better than any other for some purposes. In this contract no preference was expressed, and accordingly the expert must be assumed to decide what kind of a test should be made. "If, as a matter of fact, there is a distinction between the conditions of commercial and guaranty tests, it is a part of the expert's duty to create the conditions suitable to the form of test which he adopts. In this view we think it essential that the expert should be informed of the terms of the guaranty in order that he may apply his knowledge to the creation of the desired conditions." This particular case, therefore, depends in this respect upon whether the expert was requested to make a warranty test, which is not a detail of general interest. The importance of decision lies in its interpretation of an expert's duties in testing boilers and the recognition of the validity of tests made for the express purpose of getting the highest possible results, irrespective of the commercial or non-commercial conditions by which they are obtained.

The Joint Responsibilities of Engineers and Contractors.

The responsibilities incurred in the construction of many large engineering works are to a considerable extent carried jointly by the controlling engineers and contractors. It is true that the engineer is wholly responsible for the design in all its features and frequently for the main procedures followed in the work of construction. He takes the initiative in creating the conception of the structure or the machine designed to meet the exacting requirements of a given set of conditions in the most economical and efficient manner. It is fundamentally his duty to interpret correctly these conditions as they bear upon the interests at stake, and he falls far short of discharging his proper functions if he fails to secure satisfactory financial no less than structural results. All this pertains to the purely professional part of his operations, but there is much else to engage his most careful consideration at every stage of his work after award of the contract.

Even the most rational and effective design sets forth only the permanent parts of the required construction as they are expected to exist after completion. Indeed, it has been no uncommon experience to encounter the necessity of modifying or in some cases of radically changing many details of a design to meet successfully some feature of actual construction not before sufficiently considered, or perhaps entirely overlooked. The true excellence of a design is established largely by the convenience and economy attending the actual putting in place of that which it represents. One of the chief merits of the American pin-connection system of bridge design and construction is its combination of excellence from a purely analytic point of view with remarkable ease, rapidity and economy in actual construction. Again, the design of a masonry or other dam must involve not only the features required for retaining the proper depth of water behind it, but it must also conform to a proper control of both the ordinary and flood waters during construction. Other cases of a similar nature could be cited in great number.

Meeting these exigencies of construction or actual putting in place of the structure designed is without question one of the most important duties of the engineer, and it may be properly stated that the responsibility for this part of his work must be carried wholly by himself, although that statement may need modification in some of its applications. At any rate, there are certain responsibilities of a most serious character lying wholly with him and involving the actual operations of construction which in no way bear upon or affect the professional work of design. These are purely field operations and it is too often assumed that the contractor who undertakes the actual work of construction must carry this class of responsibilities. The latter view of the case has some reasonable foundation; indeed, that fact accounts for some of the erroneous views held in regard to this middle zone of responsibilities, and it has led to many disputes and litigations profitable neither to the engineer's client nor to the contractor.

Specifications for engineering work, especially for large works, frequently set forth in addition to the design proper certain general stipulations regarding methods of actual construction and in many cases, while prescribing general conditions, they wisely give the contractor large latitude for the conduct of his operations. In such cases he may either follow the general procedures indicated in the specifications or possibly substitute others under the approval of the engineer which may appear to him more advisable. Whether he pursues the general plans outlined in the specifications or others authorized, his responsibilities must necessarily be the same. It has frequently been contended that when the engineer sets his seal of approval upon general plans of construction by which the work covered by the contract is to be executed, he thereby relieves the contractor of at least some degree of responsibility. Although his official approval may and does carry with it certain responsibility as to the general excellence of the plan of procedure meeting his formal approval, that action cannot be construed as relieving the contractor of the burden under the contract of accepting "the sufficiency and efficiency" of his procedures. This is that middle ground of joint responsibility which every engineer should hold with the most conscientious realization of the seriousness of his position. Unquestionably it is his duty to guide the contractor in the plainest and most open manner in this part of his work. There should be no obscurity of language or veiled purpose of putting the matter in such a way as to evade consequences in case of failure or to secure commendation in case of success. Although the direct responsibility must, in practically every case, fall upon the contractor, it is the plain duty of the engineer to consider every main operation in the field with the same thoroughness and scrupulous care attending the actual design in the office. He should even scrutinize and criticise the character and amount of the contractor's plant with the view of creating such conditions as will enable the work to be done in the most economical and efficient manner, resulting not only in advantage to his client but also in business gain to the contractor.

The most excellent designing work and the most carefully conducted structural operations can easily be seriously injured or worse by inefficient or negligent operations in the progress of construction. Obviously the contractor only is responsible in such cases. Indeed "the sufficiency and efficiency" of any plan within reason is so largely dependent for successful execution upon the plant, organization and general administration of them by the contractor that he properly must assume the total burden of responsibility for the conduct of his work under the contract after the general plans of procedure are determined upon, but it is to be recognized by the engineer that he has a moral or professional responsibility in this same field, and that for the very reason of his immunity from contract liability under all ordinary or reasonable circumstances, the discharge of his part of this joint obligation should be characterized by the most scrupulous care.

The Finish of Plain Concrete Surfaces.

One of the subjects relating to concrete work which most needs discussion at the present time is the method of finishing plain exposed surfaces of this class of masonry. The trade is in a fair way to cause itself considerable trouble by its neglect to distinguish between the finish suitable for a heavy retaining wall on a branch line in the mining regions and that appropriate for the walls of a city building. Concrete is used for such a great variety of purposes that it is necessary to differentiate between the finer grades and those useful for securing mass and weight alone. If this is not done we will remain far behind the skilled concrete artisans of Europe, who will turn out one month for a facade of a building a material having a fine, close texture and clean-cut lines, and the next month a mass of rough and porous foundations for a street pavement. There can be no question about the ability of American workmen to execute heavy work in a satisfactory manner, but there can also be no question that architects and many engineers distrust their ability to cast in place walls which can be given a surface finish of a uniformity and texture suitable for a business building. It may even be said that a number of engineers hesitate to expose the surfaces of their massive concrete work in many places because they fear to risk having them discolored or marked by areas of a porous character.

Those who have looked into this subject carefully are likely to be most disturbed by the present tendency to regard as Utopian any attempt to secure a good surface for plain concrete cast in molds. That it can be done is proved by long and varied experience in Europe and by some work in this country. Unfortunately for us, there is considerable dispute as to what methods can be safely employed with American materials and workmanship, one engineer claiming success and another announcing failure for the same method. The simplest case is that of long retaining walls. Some engineers seem to be willing to accept walls which are blotched with great discolored patches and stained with gray efflorescence, others insist on a fair uniformity of color and a few demand and obtain surfaces which, like that of one of the retaining walls recently finished at the United States Military Academy, is as uniform and fine as similar work built of good sandstone or limestone. When it comes to the finish of the plain surfaces on buildings, the matter is far more important. An unsightly blotch or efflorescence streaks on the facade of a concrete building will do so much to lower this type of construction, let alone the architect's reputation, that very few members of that profession are willing to use exposed surfaces of such material. Consequently they ask for a finish of stucco or an outside course of brick or tile in order to be safe. This conservatism is natural under the conditions, but it is high time for the conditions to change. A stucco finish on a concrete wall is out of place, from the point of view of a true craftsman, and it is time to bring to light and place on record some of the methods of obtaining good uniform surfaces.

There are a number of these methods now in use, which have been employed successfully. For example, probably the best example of concrete house construction on this side of the Atlantic is the home of Mr. Alfred Mitchell, near Port Antonio, Jamaica, built by the Aberthaw Construction Co. from the plans of Mr. Horace S. Frazer. Its walls are masses of reinforced concrete, which have shown no shrinkage, although some are quite long, 73 ft. in one case and 90 ft. in another. The attractive appearance of the house is due in a measure to the skillful manner in which the surface finish brought out the special qualities of the light yellow coral rock and coral sand used in the concrete. Mingled with the coral was a little clayey earth of a brilliant crimson color. A little lime was used in the mortar to make it whiter and in conjunction with the earth produced a wall having a warm flesh tint. After the dull surface and board marks were removed by chipping with pneumatic tools or by washing with dilute acid, the resulting face was remarkably handsome.

Another piece of work which has attracted wide attention for the excellent appearance of its surface is the reinforced concrete Boulevard Bridge built under the direction of Mr. George S. Webster over the North Penn R. R. at Philadelphia. In this structure the face is a mixture of one part cement, two parts sand and three parts granolithic grit, placed against the face of the form in a nominal thickness of one inch just ahead of the body concrete. While the concrete was still fresh the face planks of the forms were taken off and the surface washed with an ordinary house scrubbing brush with water flowing over it from a sponge or hose. This removed the dull cement film and exposed the grain of the material. A general description by Mr. Webster of the methods used in this and other structures was printed in this journal on April 28 of this year, and it is accordingly unnecessary to repeat it here. Several other methods which have been used successfully are explained in Mr. L. C. Sabin's "Cement and Concrete." It is unnecessary to explain them here, as the purpose of these comments is to point out that plain surfaces of concrete can be given a satisfactory finish for most classes of structures, architectural as well as engineering. It is natural, in view of the present lack of general knowledge of the methods of securing good results, that there should be considerable hesitation in relying upon a concrete surface for many places, but as experience with good work is gained the advantages of treating the concrete so as to avoid the necessity of hiding it behind a plaster, a stucco or a veneer, will be self-evident to everybody.

Notes and Comments.

A Steel Water Tank recently placed on the roof of a Brooklyn factory fell through the five floors of the building, which was considerably damaged in consequence. About 300 hands are employed in the shop, and had the accident occurred during the working hours the loss of life and personal injuries would have been very serious. The cause of the accident has not been definitely ascertained, but it is believed to have been a defective brick foundation for the tank. Another accident of the same character happened a day later in Pittsburg, where a steel chimney on the roof of a building adjoining the Frick Building fell over and was only prevented from crashing to the alley below by being caught by a taller building across the alley. It was due to the parting of the guys. Both of these accidents again call attention to the necessity of giving careful attention to the design, construction and maintenance of all structures placed on the roof of a building. There seems to be an inherent tendency to neglect them, although the frequent serious accidents that result from doing so should be sufficient warning of the results of any carelessness.

The First Electric Train into the Grand Central Station at New York, was run down from Highbridge on September 30. Mr. W. J. Wilgus, vice-president of the New York Central & Hudson River R. R. Co., who has been in charge of all the work of improving and electrifying the terminal improvements of the company, acted as motorman of the train and, at the end of the run, received the thoroughly merited congratulations of all present on the successful demonstration of the capabilities of electric traction. By the middle of next month the public will also be able to appreciate in some degree the great improvement in service which the work of the last three years will produce, for by that time electric service will be inaugurated regularly as far as Highbridge and Wakefield on the Central lines. The smoke nuisance in the tunnel leading to the Grand Central Station will not be wholly eliminated for some months, however, for the electrification of the New York, New Haven & Hartford R. R. is not yet far enough advanced for steam to be abandoned on its lines. The electrification of the Central's lines north to Croton and White Plains is held up for the present on account of the failure of the State Railroad Commission to act on the elimination of grade crossings. Enough has already been accomplished, however, to remedy the disagreeable features of the entrance into New York by way of the tunnel, and to show to the discerning observer the marked improvements in suburban traffic accommodations which will follow the completion of this great undertaking. A minor feature of the improvements which is of interest is that the electrification of the road does away with the old method of operating trains on the left-hand rather than the right-hand track; the entrance into the Grand Central Station has been one of the very few places in the United States where this practice was followed, although it is regularly used abroad.

Foreign Street Pavements do not seem to be so wonderful to City Engineer Fendall, of Baltimore as they are often reported to be. He has recently returned from a visit to a number of European cities where he made a careful examination of street conditions, and his remarks to representatives of Baltimore papers indicate that his inspection has led him to form the same opinion that this journal has held for a number of years. His official report has not yet been published, yet it appears from his unofficial statements that he considers the best American pavements equal, to say the least, to the best of those abroad. The Engineering Record agrees thoroughly with this view. He found some of the leading streets in Paris marred by holes and ruts, just as is the case here, although there is a mistaken popular impression that a hole is never allowed to appear in a pavement on an important street in the French capital, while the whole government would be overthrown if a good old-fashioned rut were allowed to form. As a matter of fact, there is no secret knowledge in the possession of the engineers of Paris or any other European city by which they are able to accomplish paving wonders. They work under conditions which are more favorable for good results than are those in most American cities; they have more money for construction, the traffic does not include such destructive loads on narrow tires as occasionally pass over our streets, the paving gangs are not followed so closely by others which tear up the pavements to lay up all manner of sub-surface works, and the appropriations for maintainance are larger. Public opinion in Paris would never tolerate a street in the present condition of Columbus Ave., in Boston, for instance, and consequently more money is available for keeping the pavements in good condition than is the case here. Just as soon as the manifold demands on the purse of a rapidly growing American city become so adjusted that funds are available for good pavements and regulations are passed and enforced to prevent the continual tearing up of the streets, that city is in position to obtain as good pavements as those of any European capital. We have just as good engineers and materials, and the only reason we have not yet so many miles of pavements of high grade to show is that we are comparatively young, have enormous expenditures for all kinds of public work that are incident to communities of vigorous growth, and our appropriations for street improvements must be made in keeping with those for an infinite variety of other necessities.

Water Purification at New Orleans will be conducted on the mechanical system employing a coagulant, a fact that has recently caused considerable local apprehension as to the effect of alum on the consumers. As a matter of fact sulphate of alumina will not be used as a coagulant, as originally proposed, but a lime and iron process of coagulation will be followed, and it has been necessary for Mr. George G. Earl, engineer of the Sewerage and Water Board, to issue a circular concerning the proposed methods in order to convince the citizens that the purification of the supply will not really mean its contamination by noxious chemicals. The water will first be passed through a grit chamber large enough to hold about an hour's supply, where the heaviest particles of the suspended matter will be removed by sedimentation. Then lime, and soda, when necessary, will be added in order to soften the water, which will pass next through lime-mixing chambers, where it will be in motion for an hour at a sufficient velocity to keep the suspended matter and the applied chemicals well mixed while the chemical action is taking place. After this the water passes to coagulating reservoirs large enough to hold about seven hours' supply, where a large amount of the suspended matter will be deposited by the action of the lime alone. To assist in this action and bring the water to the filters in the condition for the most successful and economical filtration, sulphate of iron will be added, the circular stating that "this has the effect of giving to the water the clearness and purity which would be obtained by the use of sulphate of alumina, with the advantage that its hardness and content of carbonic acid gas are eliminated or very greatly reduced." The cost for construction and operation of the lime and iron process will not be materially more than that estimated for the process contemplated originally. It might be added in this connection that the citizens of New Orleans should recognize that the engineers responsible for the design and construction of these great works are just as desirous of preventing the contamination of the supply as are the consumers to whom the water will be delivered. These specialists are not at all likely to destroy their reputations, which have been built up by years of successful endeavor, by advising the people of a great city to use water which is in any respect unfit for a municipal supply. This self-evident fact should in itself be a sufficient answer to any such criticisms of the purification process as were lately made in New Orleans.

THE HYDRO-ELECTRIC STATION OF THE GREENVILLE-CAROLINA POWER CO.

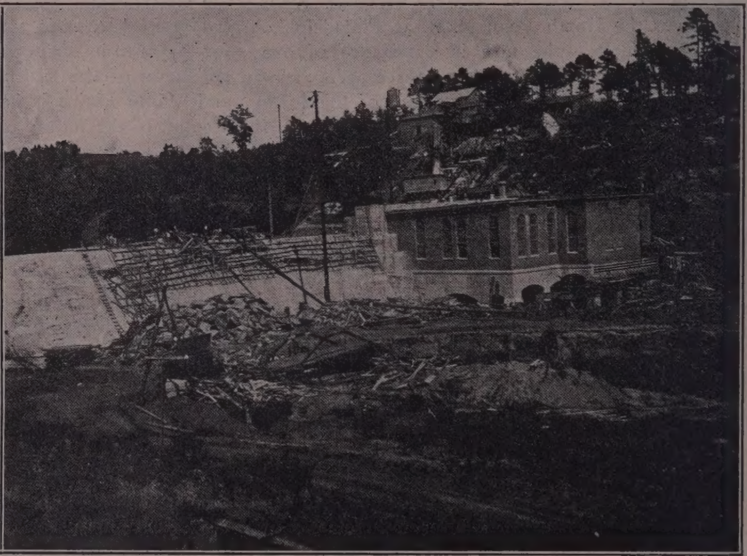
A Low-Head Water-Power Development Supplying Electric Power for Municipal, Railway and Industrial Purposes.

By William S. Ide.

The Greenville-Carolina Power Co. has just completed a dam and electric generating plant on the Saluda River, five miles west of Greenville, S. C., which supplies power to the Greenville Traction & Lighting Co. and to several cotton mills. The Saluda River rises in the mountains between North and South Carolina, and flows southeasterly until it unites, near Columbia, with the Broad, forming the Congaree River. Its water-shed of 300 square miles above Greenville, is very precipitious and consequently it is subject to sudden and unusual rises which overflow its low banks, which rises have to be contended with in building a plant of this kind.

At the site of the dam the river is about 100 ft. wide and falls about 6 ft. to the mile. Its bottom is of a shifting sand, of a good quality, under which lies a micaceous ledge of rock. On the east bank at this point the ledge rises abruptly to a height of 100 ft., while on the west bank the ground rises on a gradual slope, well above the flow line. The crest of the dam is 36 ft. above normal river level and a 36-in. flash board is provided above this, backing the water up about seven miles. To do this it was necessary to destroy two bridges and build new ones in their places, providing highways leading to them.

Method of Bonding Sections of Dam.



General View of Power House and Dam.

The contract for building this plant was awarded, under competition, to Messrs. J. F. Grandy & Son, of Greenville, S. C., but owing to financial difficulties on the part of the contractor, their contract was annulled and a new contract made with the Loring N. Farnum Company, of Boston, Mass., who carried the work through to completion with success.

The plant consists of a dam, 275 ft. long, with abutment and core wall on the west end, a head gate wall 130 ft. long, a rack wall 100 ft. in length and a power house 84 x 105 ft. in plan, with a wire tower 14½ x 40 ft. It contains about 21,000 cu. yd. of concrete masonry.

The dam proper is built on a curve having a radius of 859.92 ft. It is 47 ft. wide at the base and, by curves and batters on the down-stream face, is reduced to 9 ft. 2 in. at the top, the upstream side being vertical; 3-in. pipe, 24 in. long, are set in the crest of the dam 8 ft. on centers to act as sockets for the shafts supporting the flash board. The dam is constructed of ballasted concrete, the concrete being mixed 1:3:6, excepting on the faces where for 1 ft. in width a mixture of 1:2:5 was used.

The abutment at the west end of the dam is built in the form of steps, through which a fishway is built, and is 10 ft. higher than the rollway. From this abutment an earth dam with a core wall is projected about 80 ft. to where its top meets the natural surface of the ground. The head gate wall forms the North side of the power house and is built to the same height as the west abutment. It starts at the east end of the dam and 130 ft. east abuts in the solid ledge. This wall is 40 ft. in width at the base, and by steps on the lower side is reduced to 10 ft. at the top; it is composed of 1:3:6 concrete ballasted. In this wall are set the penstocks leading to the wheel cases, and also two 36-in. waste ways just below the penstocks, designed to carry away any sand which may deposit in the rack basin.

The rack wall just north of, and forming an angle with, the headgate wall, is a narrow wall built up to the grade of the penstocks and supports one end of the steel bents (the other end resting in the head gate wall), against which lean the rack frames and over which a platform is built. From this platform the trash and drift wood is raked up, and later carted away over a road leading out from the end of the platform.

The power house is a brick structure of mill type set on staggered piers of concrete, arched first in line forming a beam and then across from beam to beam, thus forming the floor. This gives a free outlet for the tail water on both the south and west sides of the building. A floor built over the wheel cases about 10 ft. above the level of the generator room affords a storage room 100 x 28 ft., which may be entered by stairs from the generator floor or from the outside by a door on the east side of the building.

The roof over the generator room is supported by steel trusses on steel columns, the remaining portion over the wheel cases by heavy timbers resting on wooden columns. It has a pitch of ½ in. per foot and is covered with roofing felt and gravel laid in pitch.

A crane of 15,000 lb. capacity, furnished by the Brown Hoisting Co., Cleveland, Ohio, travels the length and breadth of the generator room. It is supported by pilasters on the building end and by brackets, built on the steel columns supporting the steel roof trusses, on the other end.

The wheel equipment was furnished by the S. Morgan Smith Company, York, Pa., and consists of four pairs of 33-in. turbines, one pair of 21-in. turbines and one 15-in. wheel used for an exciter. The wheels are set in wrought-iron cases, connected with 9-ft. penstocks for the 33-in. wheels and a 6-ft. penstock for the 21-in. wheels, while a 36-in. pipe, tapped off the 6-ft. penstock just inside the head gate wall, carries water to the 15-in. exciter wheel.

A belt-driven pump supplying the water system, is connected to the shaft of the 15-in. wheel. The draft tubes are riveted to the wheel cases and are set in the concrete floor of the building. These draft tubes project 18 in. below normal water. The 33-in. wheels supply power to the cotton mills and are controlled by cylinder gates operated by Woodward governors; a Woodward governor also controls the 15-in. wheel. The 21-in. wheels furnish the power for traction and lighting and are controlled by a Lombard governor. The wheels are directly connected to the generators.

The power house equipment is arranged for the generation of 2,600 kw., 13,200-volts, 3-phase current. This total capacity is furnished by four 600-kw. generators and one 200-kw. generator, all of which are designed to generate directly 13,200-volts, 3-phase current. The exciting current for these generators is derived from two 30-kw. exciters, one 12½-kw. exciter, and one 70-kw. exciter, all 110-volts. The 70-kw. exciter is to be used as the main exciter and is direct-connected to a water wheel, in order to give it an independent drive and thus avoid any fluctuation of speed due to changes of load on the generators. Each of the 30-kw. exciters is so arranged that it can be belted to either of two 600-kw. generators and the 12½-kw. exciter is belted to the 200-kw. generator.

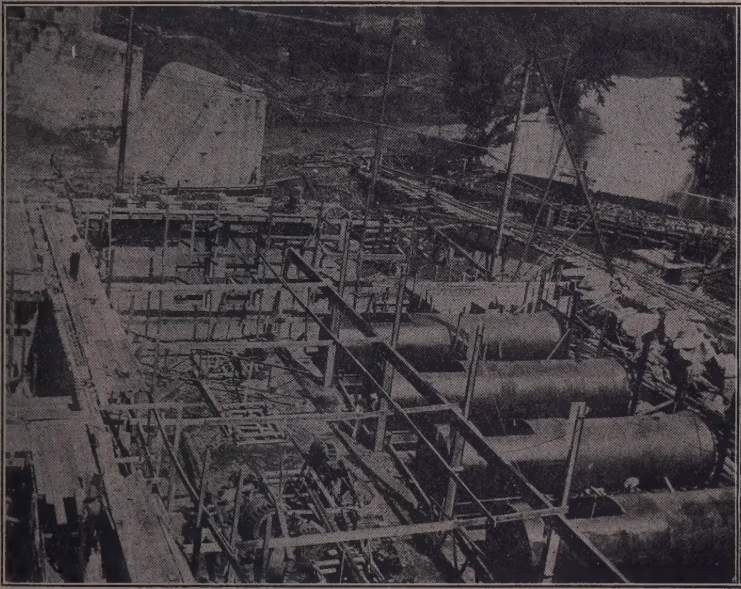
All of the wiring between the switches and machines is carried in ducts and conduits laid in the concrete beneath the floor. For the leads of the high-tension generators three-conductor rubber-insulated lead-covered cable is used. This cable is carried from the generator immediately to its 3-phase oil-insulated coil, which is connected between the switches and the generators to limit the current between machines in synchronizing and also as a lightning protection to the generator. For the arrangement of oil switches, bus bars, series transformers, and shunt transformers, a concrete bus-bar structure is used in which these various pieces of apparatus are placed in such a way as to make the apparatus for each generator in a compartment by itself. The oil switches are controlled from the panel board by means of connecting rods and bell cranks. This concrete structure is placed in an alcove and immediately in front of it, but in the power house proper, is placed the control board which consists of the ordinary generator panels, exciter panels and feeder panels. One feeder panel is placed at each end of the board and has on it the recording watt meter, ammeters and the levers for controlling the feeder oil switches in the rear. The reason for placing these feeder panels in this way is to provide for cutting the bus bars into two sections by means of the hook switches located approximately at the center. By this arrangement the entire station can be operated as two distinct units, one consisting of three 600 kw. generators and the other of one 600-kw. generator and one 200-kw. generator.

Each generator lead and also the feeder leads are connected to the bus bars by means of disconnecting switches, which are located in the circuit between the respective oil switches and the bus bars, by which method it will be observed that any high tension wires or oil switches can be disconnected from the bus bars very easily and thus allow repairs and other work to be performed on the oil switches or other apparatus with perfect safety. The rear wall of the alcove, that is the wall immediately behind the bus-bar structure, is used to accommodate an equipment of low equivalent lightning arresters; as there are two lines leaving the power station, six of these arresters are required, and each one is connected to the line which it protects by means of a hook switch, thus enabling the attendant to disconnect the arresters from the line in case of any necessary repairs. All six wires above referred to are carried through walls by means of 12-in. terra cotta pipe with a bell on the inside and ¼-in. plate glass disc inside the bell, the wire passing through a hole in this disc. All electrical apparatus for the main station including wiring, machinery and switches, was furnished and installed by Westinghouse Electric & Mfg. Co.

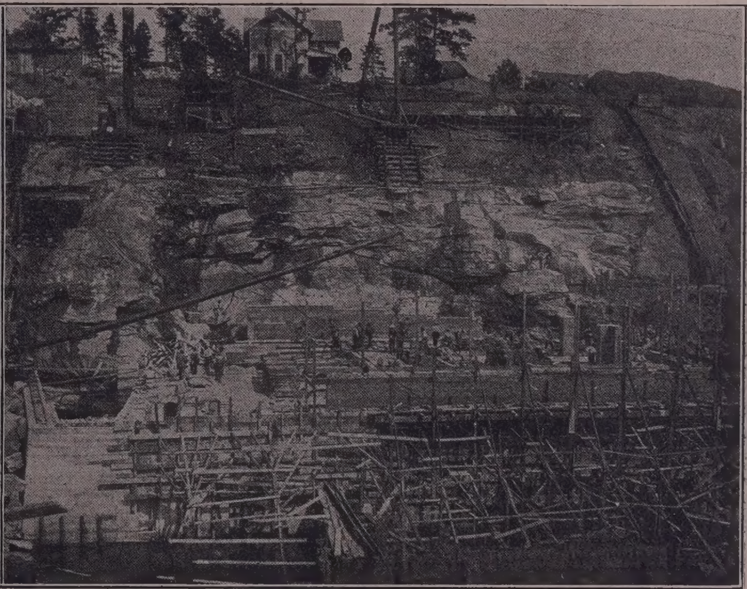
Transmission Lines.—The main points for receiving this power are three, one being the Brandon Mills, which is about 3 miles from the power house, and where approximately 1,500 h.-p. is to be used, another, the Carolina Mills, where 250 h.-p. is used, and the third being the main distributing sub-station in the city of Greenville, this sub-station being 5.8 miles from the dam. In arranging the design of this line, it was considered very important to arrange every possible safeguard to insure continuous service, as the load in the city consists largely of public service. It was therefore deemed advisable to run a double delta line and arrange switches in the sub-station and power house, so that these lines could be run in parallel, or one line could be run alone in case the other became defective, and thus allow repairs to be made on the latter without shutting off the power entirely.

The construction used in this line is all heavy and substantial work. The insulators were obtained from the Lima Co. and have 6¾-in. petticoats and are made of porcelain with chocolate-color glaze. The pins were obtained from the Locke Insulator Mfg. Co., and have a wooden top with ⅝ in. through galvanized bolt with nut and washer on the under side of the cross arm. The braces are 2 x 2 x 3/16-in. angle iron, each brace being in one piece, and are fastened to the cross arms and poles by galvanized lag screws. The wires are placed 24 in. apart, one delta line being on each side of the pole. The cross arms are of long leaf yellow pine, and have dimensions of 3¾ x 5½ in., the top or the long arm measuring 7 ft. 4 in. and the botom 5 ft. 4 in. This arrangement of cross arms was used because in case of repairing the line there is plenty of room for a man to work on various insulators, because in going up the pole he has to pass between only two wires which are placed a considerable distance apart. The poles used on this line are of Southern white cedar or juniper, and considerable care was exercised in demanding full measurements of tops and butts in order to insure full strength. The requirements indicated top measurements of not less than 8 in. and butt measurements of not less than 15 in. for a 35-ft. pole, which was the standard used.

Before beginning any actual construction work, the route of the line was carefully laid out so as to have the line as near as possible to the wagon road in order to facilitate building a new line and also repairing the same, and at the same time have as few angles as possible. As the country was somewhat rolling, a profile of the line was made and the poles locoated on it, so as to make easy curves over the hills and ravines. This was accomplished by placing poles at the sides of ravines, and in some cases by using longer poles than the 35 ft. standard length. By grading the line this way, and using the same tension in pulling up the wires any upward strain on the insulators was avoided. The method of anchoring the wires at each end of the line and also at the middle point is worthy of notice. This was done at the power house end by means of gallows construction in which five poles were used, and which were guyed strongly to dead men. The transmission wires were carried directly over the five insulators (this being the number used to hold the strain), and the insulators on double cross arms were bound together with galvanized wire. The transmission wire was fastened to this combination by a bent piece of copper wire, the ends of which were soldered to the same point on the transmission wire and the loop slipped over the top insulator. By this method it will be noted that the strain was thus transmitted to the two insulators and that the transmission wire was in no way kinked in its path along the insulators. This same construction of cross arms and anchoring was used at the middle point, which is located near the Brandon Mills. At the city end of the line it was found that such an arrangement would be too clumsy for the street and two poles were set 10 ft. apart and braced together with long cross arms, each pole having double cross arms for the transmission wires and the same method of tying being used At all angles a number of poles were set at a distance from 80 to 110 ft. apart, so that the wires could be carried around a curve, thus distributing the strain on several poles, all of which carried double cross arms and were heavily guyed.



Feed Pipes for Water Wheels in Place.



Power House During Construction.

Between the power house and the Brandon Mills sub-station No. 2 bare copper wire was used, and between that station and the one in the city, No. 3 bare copper wire. Before setting the poles, all of the butts were given two coats of a mixture of hot tar and rosin, in order to prevent decay. On an ordinary straight line where there were no particular obstacles such as ravines and hills, the spacing between poles was 110 ft. but this distance was varied at different points on the line up to 120 ft., this being the greatest distance used.

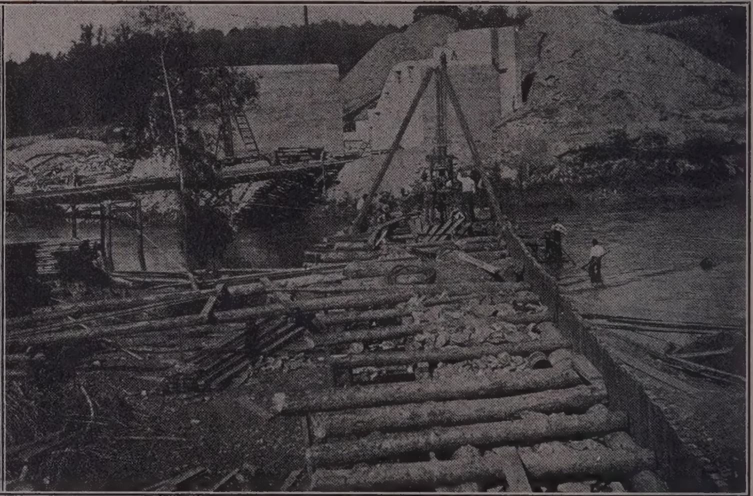
In crossing telephone lines, the spans are made as short as possible and a grounded cradle was placed below the transmission lines to prevent contact in case one of the high tension wires should fall. On Broad St., in Greenville, which is a semi-business street, and which crosses the principal business street, poles 50, 60 and 65 ft. in length were used in order to clear trees and other wires.

The cost of this line was approximately $2,200 per mile, and although the electrical features have not yet been tested, judging from a mechanical standpoint, it should give thorough satisfaction. An observer is impressed with the ruggedness of construction, the small number of angles in the country portion (there being one tangent line over a mile long), the manner of providing for these angles and the graceful curves obtained in passing over rolling country.

Sub-station.—As noted above, the Brandon Mill sub-station is arranged for the transformation of 1,500-kw., this power being used for driving the cotton mill at a voltage of 550 volts. The equipment of this station consists of three 500-kw. transformers delta-connected, fused circuit breakers, low equivalent lightning arresters and three selector switches which are used to connect the transformers to either or both of the high tension lines.

The sub-station in Greenville is for the purpose of supplying three services, one for traction requirements, a second for lighting purposes and a third for 2,200-volt distribution in the city. The first two powers are sold from the secondaries of the step down transformers to the Greenville Gas, Electric Light & Power Co., for which reason the sub-station is located on a lot adjoining their property. The power is brought to this station at 13,000 volts to avoid the necessity of having another transformation in the system with its usual objection. The two three-phase lines are connected to high tension bus bars by means of hook swiches, by which as at Brandon Mills, the transformers can be connected to either or both lines. The 13,000-volt primaries of the three sets of transformers are connected to the bus bars by fused circuit breakers, the transformers for lighting purposes being arranged to transform from 13,000 volts three-phase to 2,200 volts two-phase current, those for traction purposes to 420 volts six-phase (diametrical) and those for power distribution to 2,200 volts three-phase. Wires for the six-phase rotaries in the near-by power house and the wires for the 2,200-volt lighting service are carried to that station under ground, in multi-duct conduits. This sub-station as well as the one at Brandon Mills, presents a very substantial appearance, both being of brick, with concrete floor and tar and gravel roof.

A Flood in the River.



Cofferdam Under Construction.

Construction.—When construction of the plant was started, the first work the contractor did was to build quarters for the men. Negro cabins were built on the south end of the property to accommodate about 250 men; above these and about 1,000 ft. away, the white men's quarters and an eating house were established. The commissary was located a short distance from the negro camp, as the negroes obtained their rations here, no boarding house being needed for them. During the work of the first contractor, but few white men were employed, consequently, when the Farnum Co. took up the work, bringing with them about 80 white men, such as foremen, mechanics and general utility men, this camp had to be remodeled and enlarged. A large dining hall was built and a competent Northern cook installed.

The power company built a modern 6-room cottage to be occupied by the superintendent, a 2-room cottage for the assistants and a stable. The grounds around these buildings were nicely laid out in park style.

For fire protection, a 10,000-gal. tank was erected, 4-in. mains laid and hydrants set convenient to the buildings, water being pumped direct from the river into the mains.

On the east bank of the river and just south of the dam site, a quarry, which had been previously worked by the Southern Railway for stone used in the abutment of a trestle on which its tracks crosses the Saluda River about one-half mile south, was opened. This quarry was of a mica schist quality except in veins where good rock was found. The decision was soon made that it would not pay to work it, and another quarry about 1,000 ft. north was opened. In this second quarry an unlimited amount of good hard rock was found, and nearly all stone for crushing was obtained from it. A gravity railroad was built from this quarry to the crusher which was located on the east hillside, just north of the head gate wall of the plant. The stone cars dumped directly into the crusher and the stone, after passing through it, was deposited by a conveyor belt into bins, from which it was drawn as needed directly into the hopper of the concrete mixer.

Another quarry was opened on the west side of the river south of the dam, and from it was quarried the greater part of the ballast stone. This stone was conveyed to the work on wagons.

Along the east bank of the river above the dam, floods had deposited a large amount of sand. This sand was used for making concrete until exhausted, when it became necessary to find a new supply. Accordingly, a derrick fitted with an orange-peel dredge was set on the bank of the river, and first quality sand was taken from the river bed. This sand was hauled convenient to the concrete mixer on wagons.

First quality Portland cement, of different brands, was used throughout the job. The cement was stored in sheds on the brow of the hill just back of the crusher, and as needed, it was wheeled over a platform some 20 ft., and dumped into a chute leading to a small house set over the crushed stone bins, from which it was emptied into chutes leading directly to the mixer hopper.

One ¾-yd. Ransome concrete mixer and one Smith mixer of the same capacity were set below and at either side of the stone bin, and over each was a measuring hopper for the stone, sand and cement. From the mixer a double-track narrow-gauge railroad, extended some 40 ft. north of, and the full length of the dam, on a high trestle, which carried the track across the river, well above flood water. This railroad was graded slightly away from the mixer, so that the buckets of concrete set on a flat car would coast to their destination and when empty could be easily pushed back to the mixer by two men.

Derricks placed conveniently along the north side of the dam took the buckets of concrete from the railroad and placed them when needed, while derricks set on the south side of the dam handled the ballast stone.

Under the contract the power house was to be completed first, in order that the wheel equipment and electrical apparatus might be set in place by the time the remainder of the work was finished. Accordingly, a cofferdam was built to include the power house and tailrace, the head gate wall, the rack wall and about 25 ft. of the dam, thus narrowing the river down to about 50 ft. This cofferdam was built up about 3 ft. above normal river level. The season proved very wet, and many set-backs were encountered by the sudden rises of the river, which overflowed and scoured out around the cofferdam, causing it to leak badly when the river resumed its normal level. So that only the headgate wall had actually been started when the contract with the original contractors was annulled in December.

When work was again started, this coffer was repaired and built up about 6 ft. higher, and the work inside pushed to completion. It was necessary to excavate much deeper here for a suitable foundation than was anticipated, the rock being soft and seamy for a considerable depth.

Meantime, work was being carried on on the west side of the river. A trench 12 ft. wide and 60 ft. long was dug on the bank about 15 ft. from the river; this was tight sheathed and carried down to suitable foundations, and in it a section of the dam was built up well above river level. From each end of this section a line of 4-in. sheathing was driven, with a 1,000-lb. drop hammer, to a ledge about 50 ft. each side. This line of sheathing served to keep the river from leaking into the remainder of the excavation on the west side and later to connect the two cofferdams extending across the river. The foundation on the west side was somewhat peculiar. Good hard rock foundation was found extending about half the width of the abutment, then dropped off perpendicularly, leaving a triangle under the northwest corner where rock was not found. This ledge ran diagonally with the dam, and after about 100 ft. ran out and a micaceous rock was found. About 6 ft. of this was excavated and deep grooves cut into it lengthwise with the dam, and the masonry filled in tight against the banks. As this work was built up, four 4 x 6-ft. openings were left in the concrete to carry the river while the remaining portion of the dam was being built. The openings were spaced 8 ft. apart on centers and arched over, the concrete being brought up 4 ft. and the dam on each side was carried up to completion, thus leaving a gap about 32 ft. wide to provide for floods, which the waste way would not carry. The up-stream faces of these sluice ways were fitted with gate slides, and from the top of each opening 3-in. pipes were brought up vertically to act later, as grout pipes when these openings were filled. Canals were dug on either side of the dam to divert the river from its natural course through these 4x6-ft. openings.

While this work was in progress, a cofferdam of heavy construction was built across the river just above the dam site, and the river was then turned through the new channel. Another cofferdam of lighter construction was built across the river about 200 ft. south, thus enclosing the remaining part of the dam to be built. Little trouble was encountered here, the cofferdams proving tight, and good hard rock was found for 75 ft. under the east end, while the remaining foundation was of the same mica ledge previously mentioned. As this section of the dam was completed, masonry was started in the gap over the temporary waste ways and carried up, making the dam complete. This masonry was given two weeks to dry out and harden and then gates were dropped over the temporary openings and the river shut off until such time as it should rise to flow through the wheels, satisfactory arrangements to do this having been made with the mills below. The four waste ways were thus filled from the front, and cofferdams and other obstructions on the down stream side removed to give a clear way for the flow of water through the tail race.

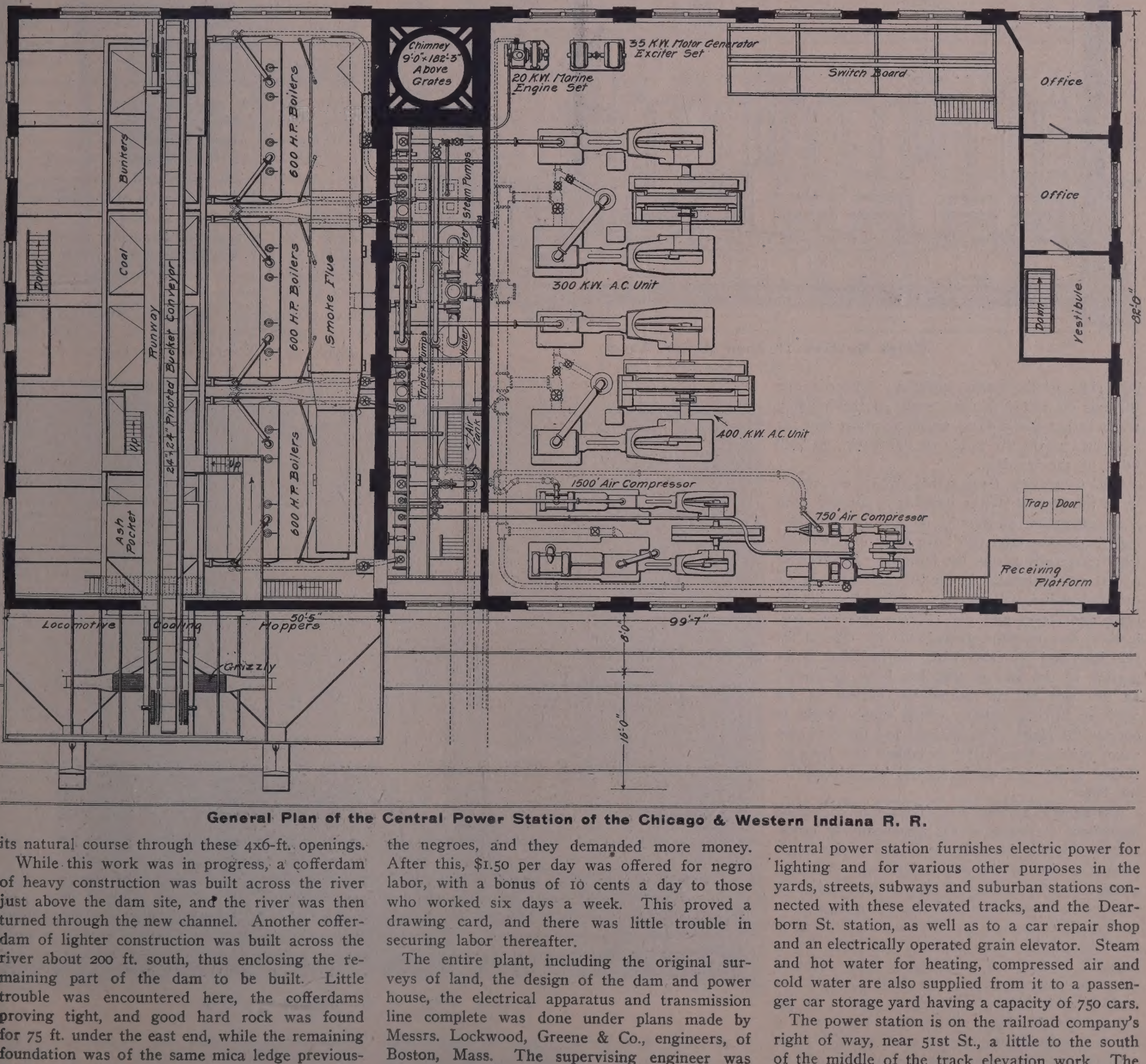
When this work was begun the contractors were paying $1 for 10 hr.'s labor; by September labor was scarce at $1.25 for 10 hrs. and when the Farnum Co. took up the work, they decided to bring in Italian labor; accordingly, quarters were built and 100 men brought down from Boston. Shortly after their arrival here one of their number died of pneumonia, and two others met with accidents; this seemed to unsettle the men and the first pay day, they declared a strike for more money; this demand was refused, and all but ten returned North. As laborers, the Italians proved no better, if as good as the negroes, and they demanded more money. After this, $1.50 per day was offered for negro labor, with a bonus of 10 cents a day to those who worked six days a week. This proved a drawing card, and there was little trouble in securing labor thereafter.

The entire plant, including the original surveys of land, the design of the dam and power house, the electrical apparatus and transmission line complete was done under plans made by Messrs. Lockwood, Greene & Co., engineers, of Boston, Mass. The supervising engineer was Mr. Wm. S. Ide, and the representative of the contractors, the Loring N. Farnum Co., was Mr. C. E. Hewins. The Greenville-Carolina Power Co. is owned by South Carolina and Boston interests; its president is Mr. Alester G. Furman, of Greenville, S. C., and its treasurer, Mr. E. F. Greene, of Boston, Mass.

The Central Power Station of the Chicago & Western Indiana Ry.

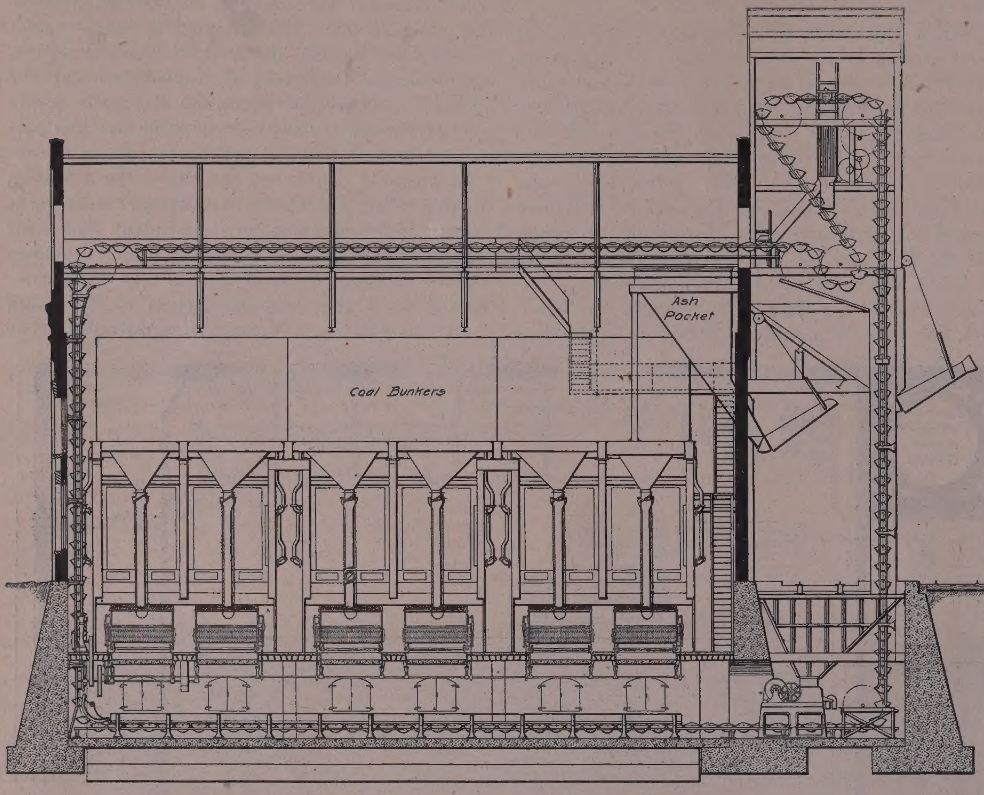
A central power station designed to meet peculiar operating requirements has recently been completed for the Chicago & Western Indiana Ry., in Chicago. This railroad is the one over which the Wabash, the Erie, the Grand Trunk, the Chicago, Cincinnati & Louisville, and the Atchison, Topeka & Sante Fe Railroads secure an entrance to the city. Its present terminal passenger station is on Dearborn St., near the central business district of the city. The elevation of this railroad company's tracks and of the yards of the railroad companies dependent on it for terminal facilities, to eliminate grade crossings on the cross-town city streets, is just being completed from this terminal station to the south as far as 81st St., a distance of eight miles. The central power station furnishes electric power for lighting and for various other purposes in the yards, streets, subways and suburban stations connected with these elevated tracks, and the Dearborn St. station, as well as to a car repair shop and an electrically operated grain elevator. Steam and hot water for heating, compressed air and cold water are also supplied from it to a passenger car storage yard having a capacity of 750 cars.

The power station is on the railroad company's right of way, near 51st St., a little to the south of the middle of the track elevation work. The station building is 82x150 ft. in plan and is built so that when its present size and capacity are doubled it will become a symmetrical structure. It has brick side walls supporting steel roof trusses carrying book tile laid in tee irons and waterproofed with 5-ply felt roofing laid in tar and finished with gravel. The building consists of an



General Plan of the Central Power Station of the Chicago & Western Indiana R. R.

engine room, 84x82 ft. in plan, at one end of the building and a 50x82-ft. boiler room at the other end, with a pump, valve and steam auxiliary room, 13 ft. wide between them. The floor of the three rooms are at the same level, 8.5 ft. below the grade of the tracks in the elevated yards on both sides of the station building. The concrete footings on which the side walls of the building are built are designed as retaining walls and are continued up to the grade of the tracks on both sides of the building.



Cross Section Through Boiler Room.

Coal Conveying Equipment.—When the capacity of the present station building is doubled, with a corresponding increase in the size of the building, the boiler room will have three bays extending transversely across the building. Batteries of boilers will be located in the two side bays, while the central bay will provide a firing floor at the main floor level and will contain overhead coal bunkers in a monitor erected over it. One of the side bays and the central bay are included in the portion of the station that has been completed. In this side bay is located the battery of six 300-h.-p. Stirling boilers, which supply steam to operate the plant. The bunkers and the coal conveyor serving this battery of boilers have been installed in the half of the central bay adjacent to the latter.

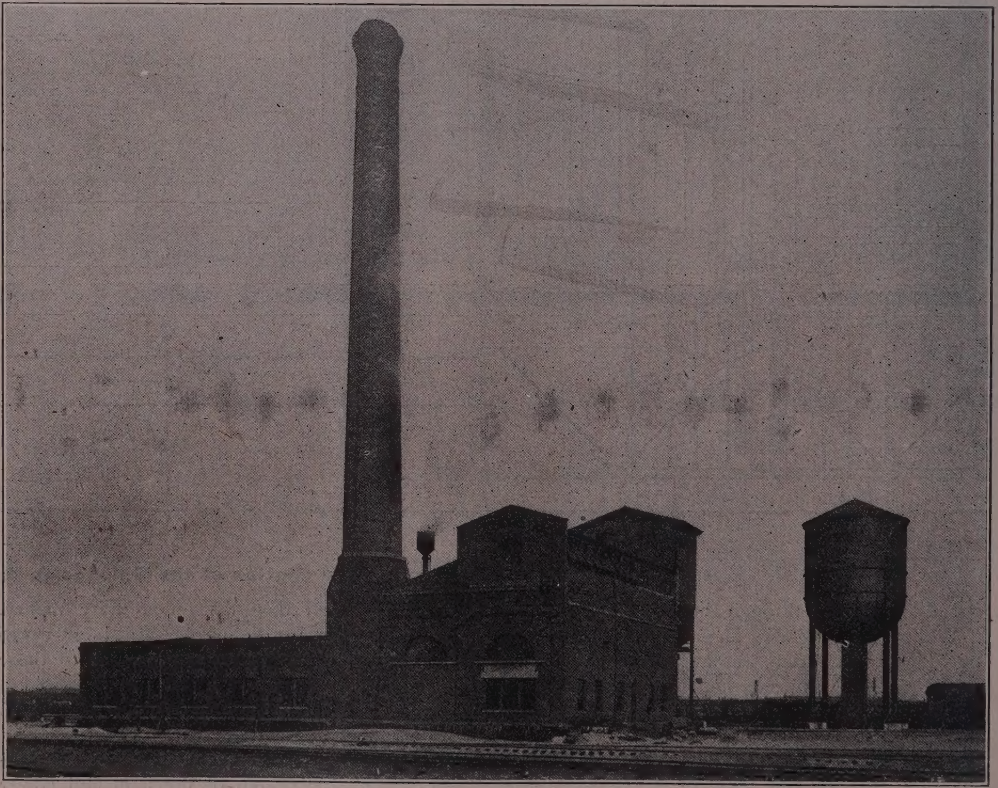
The general arrangement of the coal conveying equipment is shown in the accompanying cross-section through the boiler room and in the longitudinal section of the station building. The coal supply for the boilers of the power station is handled in conjunction with that for a locomotive coaling chute erected just outside the building at one end of the boiler room. This chute has a capacity of 200 tons, its hoppers being elevated on a steel structure so as to clear a supply and coaling track that extends along parallel to the side of the building. Over these hoppers is a cupola containing the electric motors which drive a pivoted bucket conveyor arranged as shown in the two accompanying drawings to which reference has been made.

A receiving hopper is built under the track along the side of the building and immediately under the coaling chute. Mine-run coal is dumped into this hopper, from which it is passed to a self-contained motor-driven crusher. The usual method of operation is to set the crusher so that it will pass all coal of 5-in. cubes and smaller. The product of the crusher is elevated to the cupola by the bucket conveyor, and is there discharged over a grizzly which separates the pieces ¾ to 5 in. in size and diverts them into the locomotive coaling hoppers. The small pieces and screenings that pass through the grizzly are returned to the bucket conveyor again and carried by it to the bunkers supplying the furnaces of the boilers of the plant. The bars of the grizzly may be spaced closer together in case there is not sufficient coal retained by it for the locomotives, or the limiting size of coal passing the crusher may be changed. The locomotives are in this manner supplied with clean coal of uniform size, such as is best adapted to their needs, while the fine coal and slack are consumed under the stationary boilers of the power plant where good results with it are more easily obtained.

The bunkers supplying the furnaces of the boilers of the power plant have a total capacity of 300 tons. Each boiler furnace is equipped with a Green automatic chain grate stoker, the feeding hoppers of which are supplied by chutes leading down from under-cut gates on hoppers on the under side of the overhead bunkers. These gates are controlled by chains from the firing room floor. The stokers are driven by an electric motor suspended from the ceiling of the basement under the boiler room, or by a small steam engine.

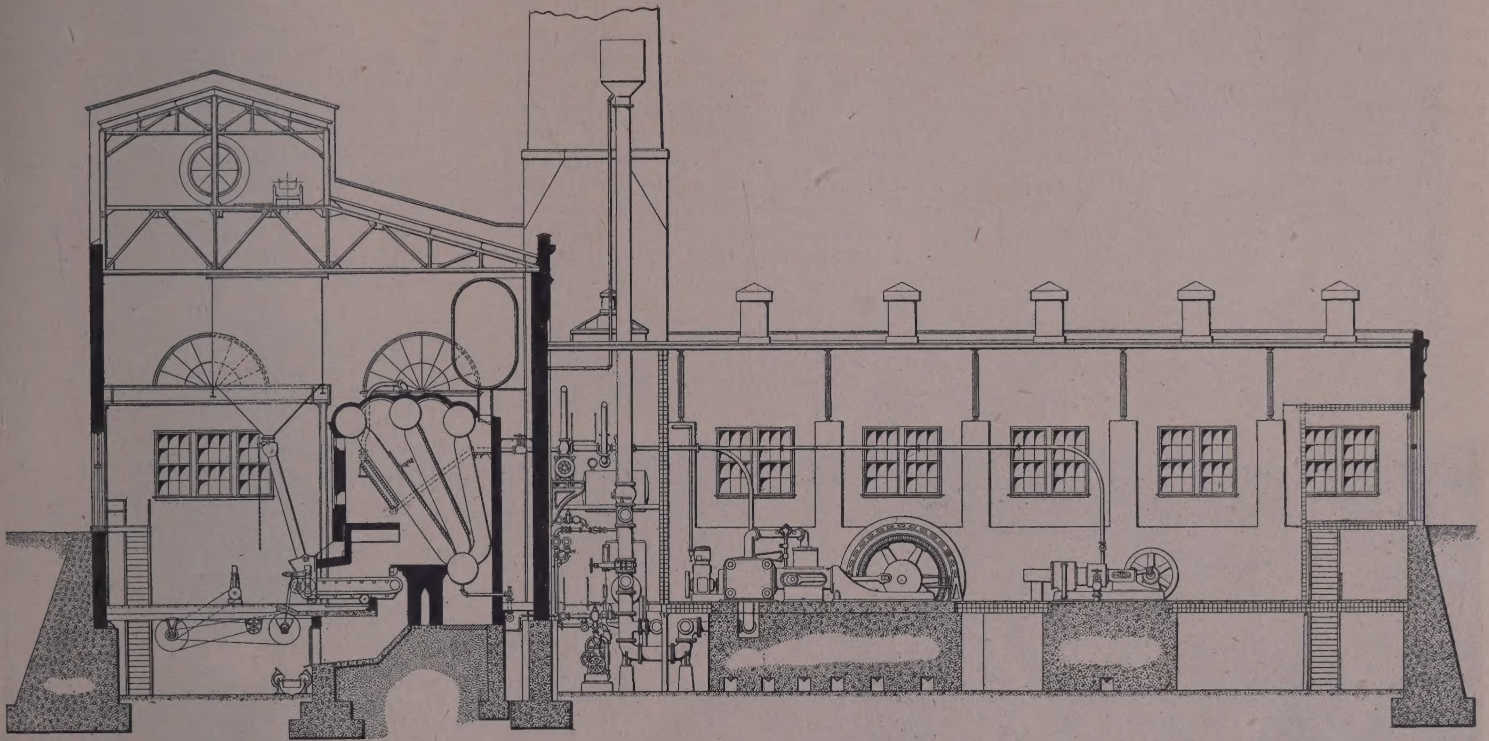
The ashes from the boiler furnaces may be temporarily stored in a small concrete-lined hopper under each of the stokers. The hoppers are provided with sprays for quenching the ashes, controlled from the boiler room floor level. The bottoms of these hoppers are so arranged that the ashes are discharged from them into the horizontal flight of the coal conveyor in the basement. The conveyor elevates the ashes to an ash storage pocket over the track at the end of the boiler room, which discharges into cars on that track.

Boilers and Steam Connections.—The six 300-h.-p. Stirling water tube boilers in the boiler room are placed in three pairs and are operated at a pressure of 150 lb. The ratio of the heating surface of these boilers to surface of the traveling chain grates is 50 to 1. The boiler furnaces connect with a breeching built up of steel plates. This breeching is suspended from the roof trusses and is insulated with 1½-in. air-cell blocks covered with canvas coated with fire-resisting paint. The breeching connects with the brick stack which serves the plant. The base of this stack, 16 ft. square and 49 ft. high, is within the building at one end of the narrow room between the boiler and engine rooms, as shown in the accompanying plan. The stack, which has a total height of 182 ft. 3 in. above the grates and an internal diameter of 9 ft., was built by the Steinl Chimney Construction Co.

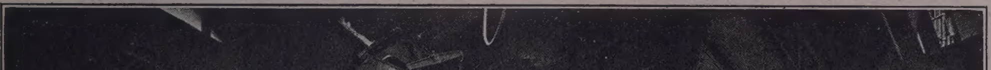


General View of the Station Building.

The boilers are equipped with Foster superheaters which are arranged, as shown in the longitudinal section of the station building, so flue gases strike the superheater at an almost maximum temperature. The arch over the grate is so placed, however, that the entire volume of gases does not pass the superheater, a portion of them being diverted up back of it directly through the boiler flues. A thermometer in the pipe to the main steam header is in plain view of the fireman so that the temperature of the steam may be observed and controlled.



Longitudinal Section Through Boiler and Engine Rooms.



Chain Grate Stokers Under Boilers

The main steam header is carried on wall brackets in the pump and steam auxiliary room. It is 18 in. in diameter, and is divided in two sections connected by an 8-in. expansion loop. An auxiliary header, to which the supply lines to the various steam consuming units are connected, is also provided, so that if either half of the main header is not in service these units may be supplied. The connections between the header and the boilers are fitted with Crane automatic stop and check valves in the boiler room and with Crosby angle valves at the header. Steam is supplied to the passenger coach yard through a 10-in. pipe controlled by a Foster pressure reducing valve capable of adjustment from 20 to 80 lb. This 10-in. yard steam line is served by either the main or auxiliary header.

A storage tank in the station is supplied with city water from a 6-in. main connecting with one of the cross-town municipal supply tunnels. A 6-in. connection is also made with a service tank in the railroad yards. This connection is fitted with a pressure regulating valve so if the pressure in the city main fails the service tank pressure is immediately turned on the storage tank in the plant. The basement of the room beween the boiler and engine rooms contains two 10x6x12-in. Marsh steam pumps, one of which supplies water to the service tank in the railroad yards. A 5½x8-in. Stillwell-Bierce and a 7x8-in. Smith-Vaile pump driven by induction motors are also provided. The pumps are arranged to receive either hot or cold water and to discharge into a hot or a cold-water header line. A sump in the basement of this pump room contains two 3-in. submerged, centrifugal pumps driven by two 3-h.-p. induction motors, automatically controlled.

The steam consuming units in the engine room are each connected to a system of exhaust pipes suspended from the ceiling of the basement under that room. This exhaust system joins in a 20-in. exhaust main suspended transversely under the end of engine room floor. The main is fitted with a riser extending above the roof and capped with a Wright exhaust head. It is also connected with two 1,200-h.-p. Vater open feed-water heaters arranged in the pump and steam auxiliary room, as shown in the accompanying general plan. These heaters are so connected that they may be operated by induction, straightway or by-passed.

The generating equipment installed in the engine room consists of two generators, one a 300 and one a 400-kw., 4,000-volt, three-phase General Electric alternating-current machine. These generators are direct connected, respectively, to 16 and 28x47-in., and 18 and 32x42-in. cross-compound non-condensing engines built by the Fulton Iron Works, of St. Louis, Mo. A 20-kw. 125-volt vertical marine-type automatic steam engine, and vertical marine-type automatic steam engine, and a 35-kw. 125-volt direct-current generator coupled to a 40-h.-p. induction motor are provided as exciters for the main generators.

A double deck switchboard, 36 ft. 2 in. long, with one tier of panels at the main floor level and the second tier directly above it, with a mezzanine operating floor built around it, is placed toward one side of the engine room, as shown in the accompanying plan. Each tier of the board consists of one 18x90-in. and thirteen 32x90-in. panels of blue Vermont marble. The instruments and apparatus mounted on the board are all finished a dull black marine. Double throw automatic oil switches connected to duplicate bus-bar are used, relays which close direct current from the exciter bus-bars through the trip coils of the switches operating the automatic control.

As the conditions under which the plant is operated are quite different from those in most municipal and electric railway generating stations, it was deemed advisable to protect the generating units as fully as possible. Each of the generator panels of the switchboard is therefore provided with a triple-pole, overload time-limit relay, and also a reverse-current time limit relay, which close a direct-current circuit from the exciter bus-bars through the trip coil of the automatic switches in an emergency. The overload relays are set for a high percentage of overload of short duration, while all the feeder overload time-limit relays are set for slight overload of long duration. The overload relays come into operation when such an overload as may be detrimental to the generators or would place an undue strain on the engines occurs, or in case dead short circuits exist on the feeder lines or bus-bars and other connections of the switchboard. Careless attempts to synchronize the generators are prevented by the reverse-current relays, which also come into operation with the generators operating in parallel, when either generator loses its field or becomes short-circuited, or in case the engines during either of them slow down and cause the generators to fall out of synchronism.

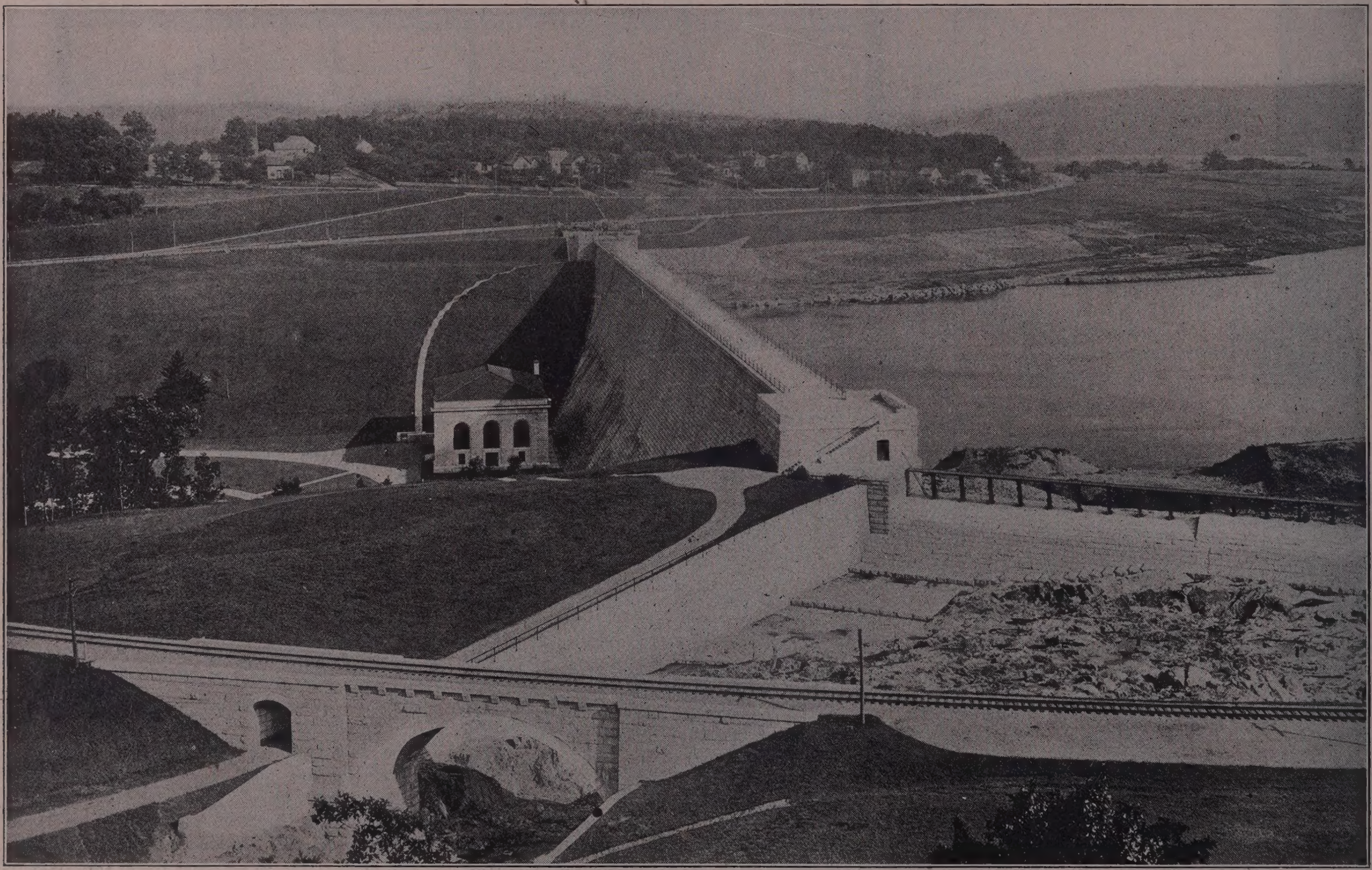
The compressed air supply for the passenger coach yards and for the station building is furnished by two compressors in the engine room. One of these is a horizontal, cross-compound, steam, two-stage compressor having 14 and 26x30-in. steam cylinders coupled in tandem to 16 and 26x30-in. air cylinders. This machine has a capacity of 1,500 cu. ft. of free air per minute at 85 r.p.m., and was built by the Fulton Iron Works, of St. Louis. The other compressor is of the Ingersoll-Sergeant horizontal cross-compound steam, two-stage air, piston-valve type with 13 and 25x14-in. steam cylinders coupled in tandem to 14½ and 22¼x14-in. air cylinders. It has a capacity of 750 cu. ft. of free air per minute at 110 r.p.m. and is fitted with Meyer cut-offs on its steam cylinders. The two compressors deliver to a receiver tank in the pump and steam auxiliary room, from which a supply line leads through the pipe tunnel under the passenger coach yards.

The grain elevator, which is supplied with power from the generating station, has a capacity of 100,000 bushels, and was formerly driven by a steam plant consisting of three 125 h.-p. boilers and two automatic engines. This steam plant has been entirely removed and the elevator has been equipped with fourteen Westinghouse-induction motors aggregating about 500 h.-p. The motors are placed in various parts of the building, some of them operating in unusually dusty surroundings. They are all controlled from a central switchboard in a separate room on the first floor of the building. When a motor is to be started the operator by pushing a button indicates a number on an annunciator on the switchboard corresponding to the number of the switch controlling that particular motor, which the switchboard tender then throws in operation. Any motor can be stopped automatically from the point where it is located by pressing a second button that throws a cut out switch on the board.

The generating station, the electrical transmission lines, and the steam, compressed air and hot and cold water distribution pipe systems were designed and built under the direction of Mr. Claude E. Stephens, consulting engineer, of Chicago. Mr. E. H. Lee is chief engineer of the Chicago & Western Indiana R. R. The steel work for the building, coal chute and coal bunkers was fabricated and erected by the Morava Construction Co. The coal handling equipment was installed by the Link Belt Co.

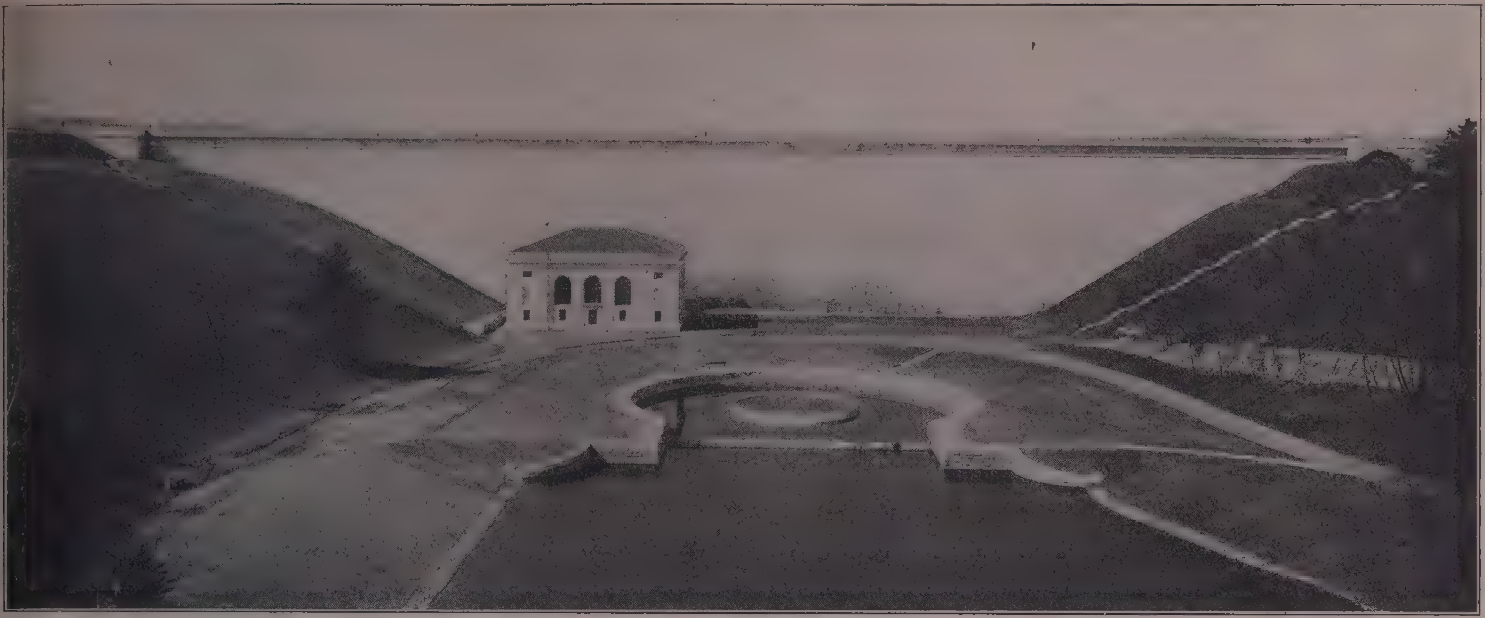
The Wachusett Dam.

The accompanying illustrations of the Wachusett dam of the Metropolitan water-works, recently completed at Clinton, Mass., give a very good idea of the appearance of this notable structure and its surroundings. Although the dam proper was finished a number of months ago, the grounds in its vicinity were not sufficiently cleaned up until recently to permit satisfactory photographs of the work to be taken. A general description of the dam and its accessories was printed in The Engineering Record of Sept. 8 and 15, 1900; an account of the contractors' equipment and methods of conducting construction was published on April 5, 1902, and some illustrations of its progress and notes on methods of handling the work appeared in the issue of March 5, 1905. These articles, with others of minor character, render any detailed description of the dam unnecessary at this time. The work has been under the charge of Mr. F. P. Stearns as chief engineer from its inception.



North End of Wachusett Dam, Showing Bastion and End of Waste-Weir.

The total length of the masonry in the dam is 1,476 ft., made up of 452 ft. of waste-weir, 971 ft. of main dam and terminal structures, and 53 ft. of core wall extending beyond the easterly terminal structures. The length of the main dam between the terminal structures is 838 ft. From the edge of the coping on the top of the dam to the original river bed is a drop of 149 ft.; the lowest point of the foundation not in the cut-off trench is 208 ft. below the coping, and the lowest point in the cut-off trench is 228 ft. below the coping. The dam and its accessory works contain 251,921 cu. yd. of rubble masonry, 8,816 cu. yd. of ashlar masonry, 2,675 cu. yd. of dimension stone masonry, 1,036 cu. yd. of brick masonry, and 9,725 cu. yd. of concrete masonry. About 260,000 cu. yd. of earth excavation and 100,000 cu. yd. of rock excavation were necessary. The rubble masonry required 184 cu. yd. of 1:1 nat-



General View of the Downstream Face of the Wachusett Dam at Clinton.

ural cement mortar, 179,706 cu. yd. of 1:2 natural cement mortar, 31,884 cu. yd. of 1:2 Portland cement mortar, 8,927 cu. yd. of 1:2½ Portland cement mortar, and 27,954 cu. yd. of 1:3 Portland cement mortar. The amount of natural cement concrete was 964 cu. yd. of 1:2:5 mix and 18 cu. yd. of 1:3:6 mix; the amount of Portland cement concrete was 7,107 cu. yd. mixed 1:2½:4½, 1,464 cu. yd. mixed 1:3:6, and 172 cu. yd. mixed 1:4:8. In the construction of the dam 182,480 bbl. of Union natural cement, and 81,103 bbl. of Portland cement, largely the Giant brand, have been used. The contract for the dam was made with the MacArthur Bros. Co., on Oct. 1, 1900.

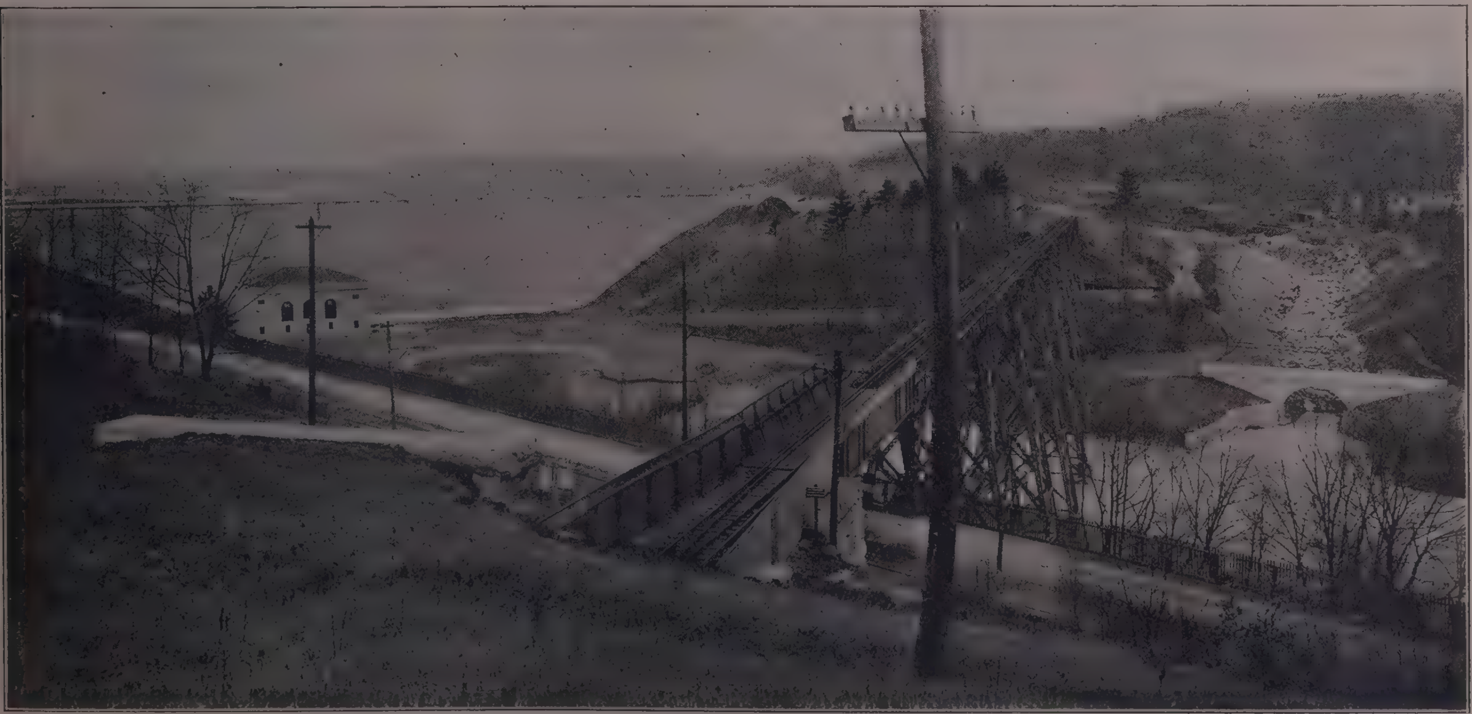
The stone masonry of the top of the dam was leveled up with concrete to about 5 in. below the finished surface, and this thickness of granolithic pavement was then laid. The entire downstream face of the dam to the ground level and the top 25 ft. of the upstream face were cleaned with wire brooms and chisels. The fence on top of the structure consists of massive brass posts on 9¾-ft. centers and two lines of 2½-in. round brass rails.

The waste-weir is 452 ft. long, as before stated, but the net waterway is but 419 ft. long, owing to the cast-iron standards placed about 10 ft. apart to support flashboards. These standards also support the steel trestles of the service walk, on which there is a track for a light car used in carrying the flashboards between the weir and the storage room in the bastion. The standards are arranged for carrying flashboards 3 ft. high except for 100 ft. of the waste-weir, where the crest is 3 ft. below the flow line and the flashboards are 6 ft. high. The flashboards above the level of the full reservoir, which is 20 ft. below the edge of the coping on top of the dam, are provided to prevent the waste of water from waves passing over the crest of the waste weir.

Extending from each end of the dam to the bottom of the valley are flights of granite steps, 187 on one hillside and 177 on the other. These are 5 ft. long, have a 7-in. rise and 12-in. tread, and are supported at the ends on concrete walls 14 in. thick and about 4½ ft. deep. The steps are arranged in flights of five to twelve, with granolithic platforms of varying lengths between them. At the top of each third flight there is a drainage inlet, connected with a system of 12 and 15-in. vitrified clay pipes which drain the grounds below the dam. To care for the water which falls on the lower face of the dam a paved gutter has been built on both hillsides, extending from the abutment and bastion to the lower gate-chamber and connecting with the pipe drains.

The work of removing soil from the reservoir was finished early last November. In all 6,912,052 cu. yd. were stripped from 3,941 acres, and it is interesting to note that of this large volume but 17,367 cu. yd. had to be placed in spoil banks. Nearly all of it was used in constructing the large dikes which close two low places in the natural rim of the reservoir basin, and the remainder was used for highway or railroad embankments, filling areas of shallow flowage or for grading grounds near the main dam.

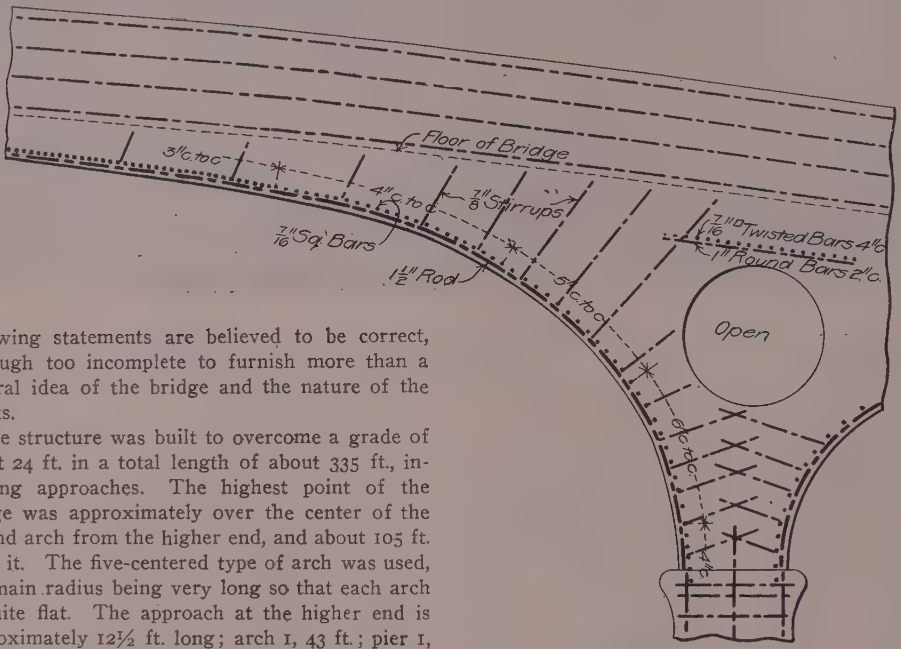
To obtain the elevation of the ground water in different parts of the north dike during the time the reservoir is filling, fifteen 2-in. wells have been driven at different points in this great embankment. The deepest well has a depth of 90 ft., and the average depth of the fifteen is 52 ft.



View of the Wachusett Dam from the East, Showing Spillway Channel.

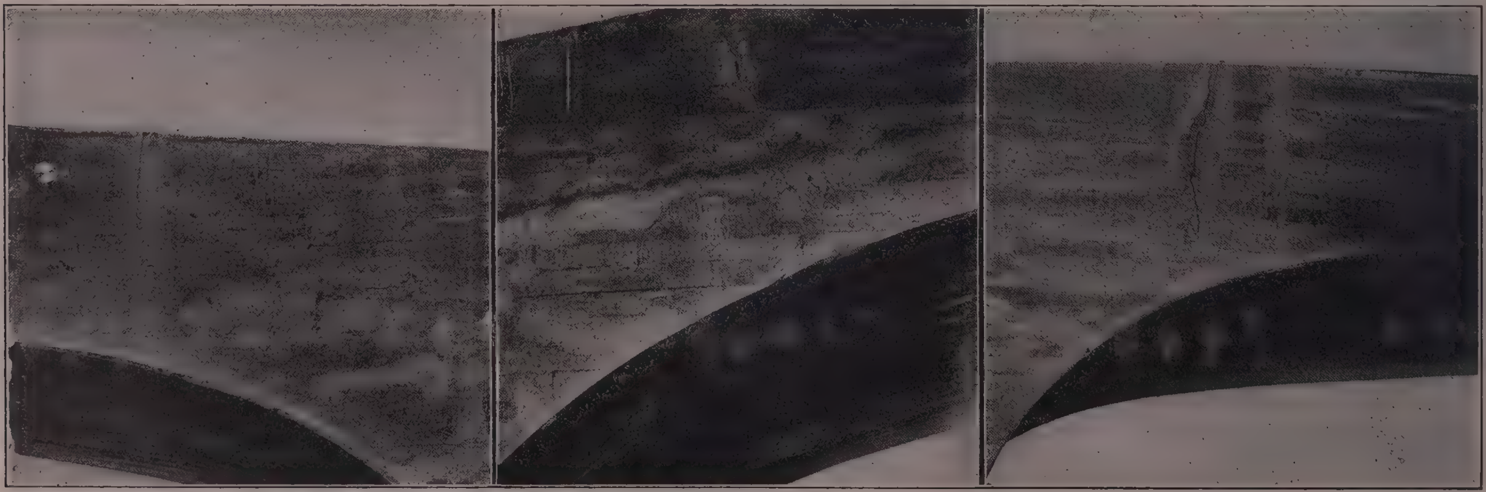
The Cracking of Reinforced Concrete Arches at South Pasadena, Cal.

There was recently constructed at South Pasadena, Cal., a five-arch reinforced-concrete bridge in which cracks have since appeared in the haunches, extending up into the parapet walls. The bridge was built over some railway tracks in order to develop a tract of land which a real estate company is placing on the market. The amount of available information concerning the structure and the cracks is very limited, but the following statements are believed to be correct, although too incomplete to furnish more than a general idea of the bridge and the nature of the cracks.



Reinforcement at Haunch of Arch 2.

The structure was built to overcome a grade of about 24 ft. in a total length of about 335 ft., including approaches. The highest point of the bridge was approximately over the center of the second arch from the higher end, and about 105 ft. from it. The five-centered type of arch was used, the main radius being very long so that each arch is quite flat. The approach at the higher end is approximately 12½ ft. long; arch 1, 43 ft.; pier 1, 6 ft.; arch 2, 78 ft.; pier 2, 6½ ft.; arch 3, 59 ft.; pier 3, 6 ft.; arch 4, 44 ft.; pier 4, 5 ft.; arch 5, 39 ft.; approach, 36 ft. These figures were scaled from a blue-print and are doubtless subject to minor corrections. The bridge is 19 ft. wide between the thin parapet walls and has two 3-ft. cement sidewalks and a roadway of 1½ in. of asphalt.



Views of Cracks in the Haunches of Three of the Arches of the South Pasadena Bridge.

The general construction is evident from the accompanying reproduction of a blue-print showing a part of arch 2, the largest in the bridge. At the center of the span, the arch is approximately 1 ft. thick, and over pier 2 it is 3 ft. 10 in. The radius of the main part of the span scales at about 180 ft., and the others at about 15 ft. and 10 ft. There seems to be no reinforcement in the upper part of the arch, unless the four longitudinal lines of ¼-in. square twisted bars in each parapet are so regarded. The lower part of the arch is reinforced 2 in. from the surface by 32 round 1½-in. longitudinal bars running from pier to pier, and by transverse 7/16-in. square twisted bars 3 in. apart over the main part of the span and farther apart toward the ends, as shown in the diagram. Stirrups of 7/16-in. square twisted bars were also used in the haunches, and there were rods above a cylindrical opening over each pier.

No information is available concerning the proportions and materials of the concrete or the character of the workmanship. Arch 1 remained 24 days before the forms were removed, arch 2 was given 25 days, arch 3 was left 22 days, and 21 days were allowed arches 4 and 5 after completion before the forms were stripped.

The character of the cracks that have since appeared in the haunches is evident from the photographs. Those in arches 2 and 3 extend within 6 in. of the bottom of the masonry and those in the other spans within a foot of the bottom. They open a quarter of an inch at the top in the early morning and by 2.30 p. m. they are almost closed. The bridge has been tested since the appearance of the cracks, and a deflection of 3/16 in. was detected in the center span under a load of 18 tons. No sinking of any of the piers has been observed. The bridge has been accepted from the contractors.

A MUNICIPAL WATER DEPARTMENT in a Kentucky city has no power to distribute water to consumers outside its boundaries, according to the Court of Appeals of that State, 94 S. W. Rep. 25, although it may sell its surplus supply in bulk to private or public parties for such distribution.

Boiler Plate Corrosion.

Boiler plate corrosion is the subject of a bulletin recently prepared by Messrs. Ch. Fremont and F. Osmond, and published by de la Societe d'Encouragement pour l'Industrie Nationale, Revue de Metallurgie, of Paris. The assumption is made in the bulletin at the start that acids alone have the power of inducing oxidation in iron, and that it is most likely carbonic acid, which actually produces this change, while oxygen only serves to raise the first-formed protoxide to a higher degree of oxidation. It is also assumed that the hammering or working of the metal renders it more liable to attack by this corrosive action than originally. The local corrosions in steam boilers are classified in two groups: Those taking the form of pustules or pitting, and those giving rise to striations or fissure-like marks. The characteristics of both groups are discussed, but the bulletin has to do only with the latter group, which are considered to probably be due in the first instance to certain mechanical causes. The corrosions taking the striated form, it has already been observed by Mr. Desgeans, are met with in certain parts of the boiler plates, where the metal has to undergo a series of flexures resulting from the successive expansion and contraction of the boiler when in service, and that the fatigue of plates thus subjected may possibly have a great influence in producing these results.

It is shown that if a homogeneous plate were covered with a uniform layer of oxidation, gradually increasing in thickness, since the coating is practically incapable of deformation, a time would come when the elastic flexure of the plate itself would effect the rupture of this coating of oxide. Such rupture would occur in the locality where the fatigue was greatest, and would follow the lines of the direction of the resultant of the force tending to produce such flexure. This rupture in the coating would leave an exposed surface of the metal to be attacked again by the corrosion, and to be in turn, ruptured, thus eventually forming a crack in the plate.

Micrographic investigations were made of iron and steel plates from four locomotive boilers of the Western Railway of France. The result of these investigations were in accordance with those of the experiments made some time ago by Messrs. Sidney A. Houghton and F. Rodgers, which later results were presented before the Iron and Steel Institute. In numerous cases the results coincided with the assumptions that had been made. A wavy appearance in the microstructure of certain specimens investigated with regard to the causes of boiler explosions is believed to be due to imperfections in the polishing and the mode of attack.

Reinforced Concrete Tunnel Caisson.—II.

Construction and Sinking.—In construction, after the steel cutting edge had been set on the surface of the ground as shown by the accompanying photograph taken Dec. 14, it was sunk about 6 ft. and was leveled up at that grade. The base of the walls of the caisson was given a bearing on the mud by tamping it thoroughly under the lagging of the stepped form. It was calculated that the bearing power of the soil would be sufficient to sustain the weight of the first deck of concreting until sinking should be started by caisson excavation. There was considerable settlement, however, during concreting, and more during the interval which elapsed after concreting was finished before sinking commenced. This settlement was not uniform, in consequence of which the caisson cutting edge was about 4 ft. out of level when construction started. In starting the sinking it was necessary to level the caisson up, a difficult problem on account of the nature of the material encountered, which was old filling of non-uniform quality. It was also complicated by encountering three old sunken barges which had to be cut up, and also because of finding piling in place along one side, and directly under the cutting edge. The caisson was finally leveled up without mishap, though the bearing against the side which had been low was consequently less than on the other side, and to keep the caisson level during sinking required constant watching.

The steel cutting edge, 3 ft. deep, was assembled in sections about 20 ft. long, supported on short transverse wooden blocks spaced about 10 ft. apart. It was made with one vertical and one inclined ⅝-in. plate shop riveted together, with a 9x⅜-in. filler plate at the bottom and with 3x½-in. bent plates 20 in. apart at the top where there were two horizontal rows of holes at 4-in. pitch to receive ½-in. boat spikes securing it to the vertical 2-in. tongue and groove boards 18 ft. long, forming the outside of the concrete mold, which were battered 1/16-in. per foot to reduce the frictional resistance. They served as permanent sheathing for the concrete and were secured by single lines of horizontal 6x3½x⅜-in. angles about 6 ft. apart vertically. The upper line of angles was flush with the tops of the boards and its horizontal leg served as a flange bolted to the corresponding flange of the lower angle in the next course of vertical sheathing boards which were thus built up in sections similar to the walls of a cofferdam. Those lines of angles opposite springing lines had their horizontal flanges bolted to the flat steel anchor bars shown in the drawings, which were provided to secure the centers and bracing of the inside arches to the walls and to provide for the transmission of stresses developed in sinking.

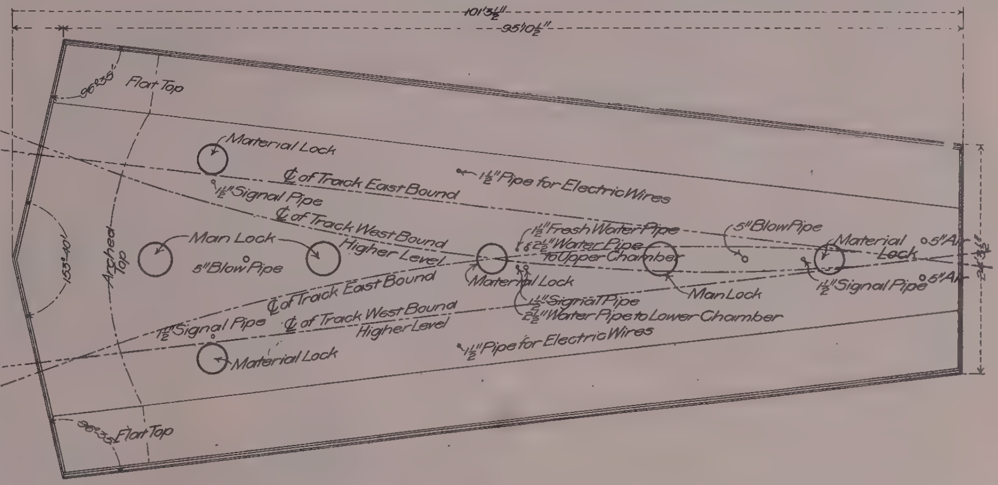
Cutting Edge Assembled on Surface of Ground.

The caisson contained approximately 200 tons of steel including the steel cutting edge, and about 3,000 cu. yd. of 1:2:4 concrete. The reinforcement used was all either second-hand railroad rails or 1 in. square twisted steel bars. The steel used for these bars was 0.012 carbon open-hearth steel, which was delivered to the job as plain square bars and later twisted by contract with the Turner Construction Co., who set up a twisting plant on the job for the purpose. The original design was to use the plain square bars, but experimental tests showed that a considerable increase in strength was obtained by twisting the steel.

On account of the large dimensions, heavy weight and great stresses developed in the caisson and the possible danger of cracks due to distortion or excessive stresses and because of the known permeability of concrete, it was feared that there might be a serious loss of air pressure through the walls of the caisson and to prevent it, a special air tight temporary lining was provided for use in sinking it. It consisted of two-ply Siastex waterproofing fabric laid over all the interior surface of the lower chamber with three coats of Carboron amalgamating solution. The fabric was received in rolls containing 450 sq. ft. of material 3 ft. wide, which were cut at the site into sheets of convenient sizes for two men to handle. These were laid on a horizontal platform near the point of application and thoroughly coated on one side with the solution applied cold with an ordinary tarring brush. Several sheets having been coated they were, for convenience, folded transversely in the middle, coated side in, and delivered to men in the caisson who unfolded and applied them to the outer surface of the planed lagging previously erected for the side walls and roof arch of the lower chamber, handling it in the same manner as wall paper is hung.

Operations were commenced at one point in the cutting edge and the men worked completely around the caisson to the starting point, applying the fabric in successive vertical strips to form a course about 6 ft. high. After its completion a second course was carried around in the same manner and so on until the outside of the lagging was covered from starting point to the crown of the arch. A second course was applied in the same manner and finished with a final exterior coating of the cold solution. The second layer broke joints both vertically and horizontally with the courses of the first layer, and special care was taken in applying the fabric to lap all joints 2 in., and to flash it for 6 in. beyond all projections and intersecting pipes, rods, and shafts.

In making the joints between the successive courses the upper edge of the outer layer in the lower course was stripped down about 6 in. and the lower edge of the first layer of the upper course was applied on top of the upper edge of the first layer of the lower course. The upper edge of the second layer of the lower course was then replaced and the lower edge of the second layer of the upper course was placed over it, thus dovetailing the two layers of both courses together. About 8,000 sq. ft. of surface was thus very satisfactorily protected by a tight elastic covering which was applied in about one week under the personal direction of Mr. Herbert Paschke, waterproofing specialist. The protection was not intended to be permanent and was not valued in this instance for its waterproofing qualities, since it was on the inside of the concrete and would not resist water pressure, and it was to a large extent stripped off with the lagging when the latter was removed after the caisson sinking was completed.



Top of Caisson No. 1.

During the sinking of the caisson, little, if any, loss of air was attributed to leakage through the walls of the caisson, but as great pains were taken with the quality and placing of the concrete some doubt was felt as to whether the air proofing was necessary or whether the concrete alone was air tight. To decide it, air pressure was admitted to the upper chamber of caisson No. 1 and the loss occurring through the concrete was so much that it was decided to use the same air-proofing process for the lower chamber in caisson No. 2.

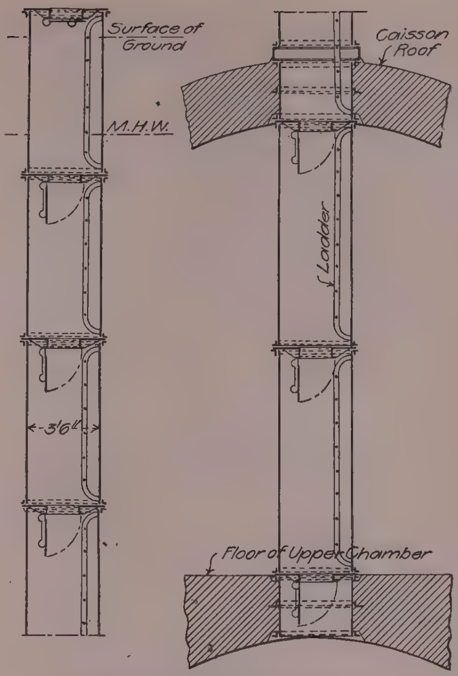
Concrete and muck were handled by two locomotive cranes on a falsework from 16 to 34 ft. in width and about 18 ft. in height, which was built around the caisson site before the construction of the latter was commenced. This had a solid platform of 3-in. planks supported on the caps of framed bents 12 ft. apart built chiefly of 12x12-in. timber and 3x12-in. diagonal braces. Tracks on both sides of it were provided for the locomotive cranes and for 21-in.

gauge service cars, and were connected by trestle extensions eo the shore shaft of the river tunnel. A storage pile of stone and sand was made in the space between the railroad tracks west of the caisson and a stiff-leg derrick delivered material from this pile and from cars on these tracks to two No. 4 Smith mixers, which were set up under the north stiff leg, with a working platform above, high enough to allow the tilting of the mixers beneath. A measuring hopper with the top flush with the floor was divided vertically by a partition separating stone from sand and so arranged that it would hold 10 cu. ft. of sand and 20 cu. ft. of stone when filled flush with the floor. On top of this 5 sacks of cement were dumped when the mixers were charged. Water was put into the mixers by buckets full through funnels discharging into the spouts of the mixers simultaneously with the other ingredients. Materials were hoisted in one-yard buckets to bins back of the mixer platform, which held approximately one hour's supply.

Construction work on account of the caisson was begun Nov. 30, 1905, when the carpenter work on the trestle was commenced. The cutting edge was put together by Dec. 14, 1905, and forms and reinforcement were ready so that concreting was started on Jan. 18, 1906, and the first deck of concreting was finished Jan. 29, 1906. The sinking was delayed in starting owing to failure of delivery of lock shafting and did not start until Feb. 26, 1906, from which date until June 7, 1906, the sinking continued, except during time taken to construct the upper deck, being completed on the last named date. The invert was placed June 7 to 12, 1906, after which the timber forms were taken apart and removed through the lock shafts under normal atmospheric pressure. The south or lower tunnel was driven into the caisson by July 5, 1906.

The concrete work was finished up to the floor of the upper chamber in about one week with 50 men continuously at work. The reinforcement steel was carefully secured in the required position in the forms and the concrete was filled in so as to keep close up to the level of the air proofing. As soon as possible after the lower half of the caisson had been built, air pressure was admitted to its chamber, excavation was commenced and it was sunk until the top was at about the ground level and there stopped while the upper half was built in the same manner that the first half had been.

In the early stages of the work, some of the concrete was handled by steel mine dump cars which were not used later in the work. A maximum amount of about 250 cu. yd. of concrete was put in place in 24 hr., with a total maximum force of about 200 men employed on the caisson in all capacities. The compressed air in the working chamber was furnished from the power plant at the main shaft of the river tunnels about 300 ft. from the caisson and varied from 2 to 28 lb. per square inch. The earth excavated from the caisson was removed by dump cars on the falsework platform until the roof of the upper chamber was sunk below the surface of the ground, after which all of the earth excavated from the interior was used as backfill piled on top of the caisson to help sink it and level up to the ground above it, access being provided for the working chamber through man and material shafts of special design which enabled them to be withdrawn after the completion of the work.



Man Shaft and Locks.

Lagging for Arch Construction.

The man shafts, 3½ ft. in inside diameter and about 60 ft. long over all, were made with a special connection at the caisson roof where they were joined with an inside and an outside flange arranged so that the connection bolts could be removed from the interior and the upper part of the shaft removed. The shaft was made in sections from 8 to 12 ft. long with horizontal diaphragms in the joint between each section. The diaphragms were pierced with manholes provided with gasketed doors opening downwards so that each section could serve as an independent air lock and enabled the whole or a part of the full length of the air shaft to be used as an air lock and thus regulated the air wasted to correspond with the size of the party emerging at each operation.

Each section of the shaft accommodated four men so that the use of the full length of the shaft as a single lock enabled 24 men to enter or emerge at once. The diaphragms were single cast-iron plates 1¼ in. thick, stiffened with vertical webs and provided with riveted steel doors. The caisson was equipped with two regular man shafts and one extra man shaft and with four material shafts 3 ft. in diameter having O'Rourke air locks made for this work, with special doors, each divided into two and hinged on the curved sides so as to revolve close to the walls of the shaft and provide maximum clearance for the buckets. All of the shafts were enclosed by wooden sheeting permanently buried in the back fill which prevented the earth and muck from packing around them so as to prevent their withdrawal. The caisson roof was pierced with four 1½-in. signal pipes adjacent to the material shafts, two 5-in. blow-out pipes, two 5-in. air pipes, one 1½-in. fresh water pipe, one 2½-in. salt water pipe for filling the upper chamber, one 2½-in. pump pipe in the lower chamber and two 1½-in. pipes for electric wires.

The caisson was sunk through about 20 ft. of soft mud and sand and 40 ft. of hard strata to a bed of sandstone which it penetrated to a depth of about 20 ft., thus justifying the assumption that the invert would not be subjected to the maximum theoretical stress. During excavation some difficulty was experienced on account of the lack of uniformity in the character of the soil which allowed one corner of the cutting edge to settle below the rest, although care had been taken to build it up to a uniform height throughout. Some difficulty was experienced in plumbing the caisson, which was eventually accurately accomplished. The most rapid progress in sinking it was about 2 ft. in 24 hr. The caisson reached its final position on June 7, 1906, sinking having been started Feb. 24, 1906. The rock in the bottom of the working chamber was dressed to sub-grade and the invert was built under air pressure, afterwards, the caisson having been thus sealed, the centers and lagging were removed, the air pressure was discontinued, and the caisson was found to be entirely waterproof. Compressed air was admitted again when the openings were made in the bulkhead for connections with the tunnel tubes.

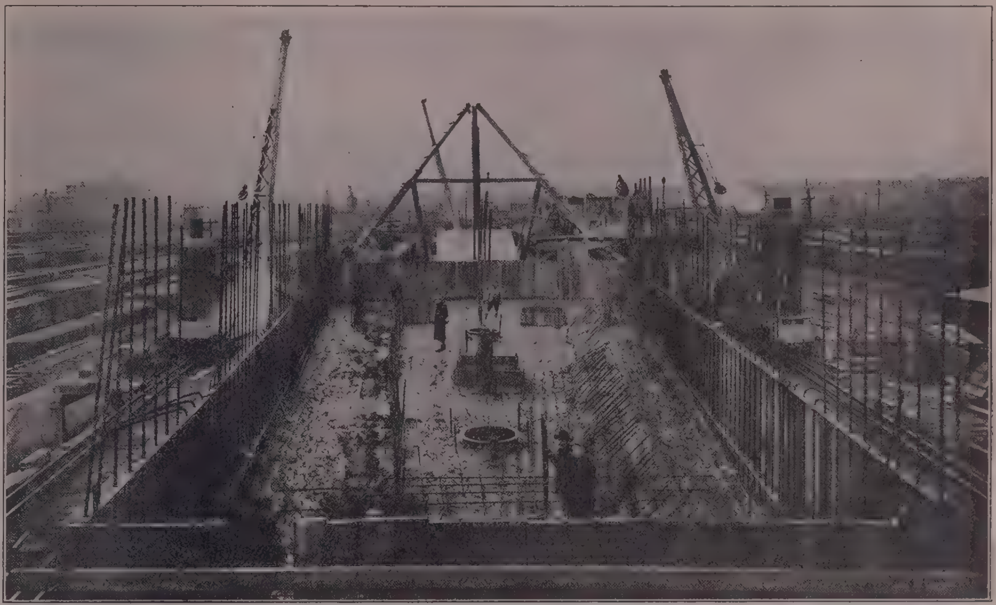
To sink the cutting edge to its final position, 77 ft. below the bottom of its 6-ft. trench, it was necessary to excavate about 11,000 cu. yd. of material, about 3,000 yd. of which was solid rock, requiring some blasting, though it was mostly soft enough to be handled with picks and bull points. It was necessary to break it all up into pieces small enough to be taken out in the caisson buckets. About 5,000 cu. yd. of this material was dumped on top of the caisson itself after the top of same went below ground level.

The daily progress reports on the caisson made by the works manager to the chief engineer included a tabulated statement of weight of caisson; material encountered; air pressure used, and calculations as to skin friction on the sides of the caisson. There was hardly any way possible to determine how much bearing the cutting edge was receiving directly on itself, and hence it was assumed all the time to be zero, although at some times it was known to be considerable. The uplift due to air pressure was taken as acting upwards over the whole area inside the cutting edge. After the caisson had disappeared below ground the area exposed to skin friction was still assumed to be all the area up to top of ground, as that part of the earth above the caisson was receiving friction from the backfilled earth.

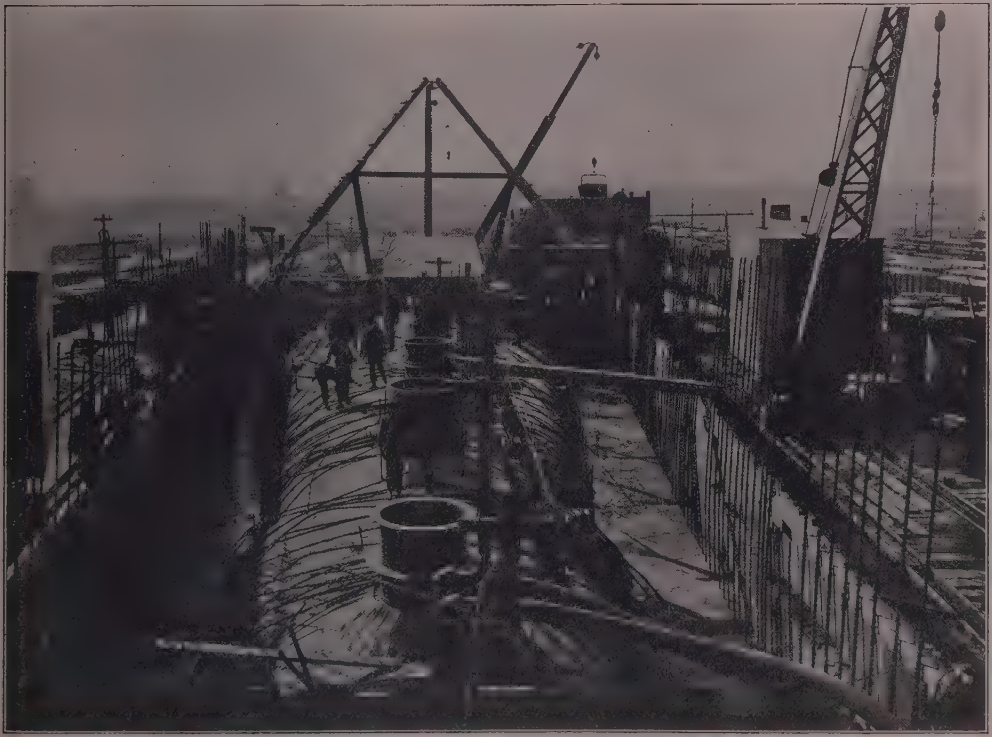
These reports show a skin friction per square foot varying from 387 lb. to 1,183 lb., but averaging about 500 lb. (At the time the report showed 1,183 lb. it was known that very much of the load was being received directly by the cutting edge.)

On Sept. 19 caisson No. 2 had been built and sunk to within 24 ft. of its final resting place, and it is anticipated that it will be finished and the invert placed ready for the reception of the tunnel shields within six weeks from that date. The design of this caisson corresponds with that of caisson No. 1 except that the plan and dimensions vary to suit the different arrangements and angles of the tunnels connected. The method of sinking it is like that already described, and the plant is substantially the same. Muck is hoisted through the material shafts by a locomotive crane and a derrick, and is dumped in elevated hoppers movable around the falsework platform, which deliver into dump cars pushed by hand to the river side where they deliver to scows. An ingenious arrangement is provided for loading the scow. It consists of an inclined apron or chute, hinged at the upper end to the edge of the falsework platforms where the cars run. The lower part of the chute is supported by a transverse bent pivoted to it near the middle. The lower end of the bent is provided with wheels seated on the deck of the main pier at ground level. The apron tends to revolve by gravity to a vertical position pushing the foot of the supporting bent backwards from the face of the pier, but its movement is commanded by a tackle attached to the axis of the wheels and leading over a snatch block on the edge of the pier. By slacking off this tackle, the chute is lowered to any angle required to suit the position of the dump scow or to distribute the material over it for proper trim. If it is necessary to elevate the chute to clear the scow or any other boat in the slip it can be easily and quickly accomplished by operating the tackle. The tunnel construction is being carried out by the Hudson Companies, and the design, construction and sinking of the caissons was carried out under the personal direction of Mr. Charles M. Jacobs, chief engineer; Mr. J. V. Davies, deputy chief engineer. The construction and sinking of the caisson was in charge of Mr. R. S. Courtney, works manager, and Mr. W. M. Torrence, superintended the caisson construction and also worked out the details of the design and made the necessary computations. The sinking was done under the direction of Mr. Samuel Matson, Superintendent, who also made valuable suggestions as to details of the design.

The Logan Iron Works was the contractor for the steel cutting edge and the Turner Construction Co. was the contractor for the reinforcement rods which were twisted at the site. The Sicilian Asphalt Paving Co., New York, supplied the material for air proofing the working chamber.



Concreting Arch Over Lower Chamber.



Lower Arch and Reinforcement Rods for Upper Chamber.

Sewage Flow at Waverly, N. Y.

By Clyde Potts.

In the design of sewers one of the indeterminate factors is the probable amount of sewage for which to provide. At the same time it is one of the most important factors, for while the cost of the sewers does not increase directly proportional to the size, the size largely governs the cost. It is a waste of money to provide larger sewers than necessary, and again there is great antagonism in lay minds against small sewers because of the tremendous trouble generally experienced in the past by undersized sewers. There is a considerable element of guesswork in the formula employed in the design of sewers, one of the most uncertain factors being the per capita consumption of water. In fact, there is much to criticise generally in the formula employed in computing the size of sewers, in the construction of which there has been an absence of reliable experimental data on which to base the coefficients. It should be kept in mind that sewers laid with 3-ft. lengths require a cement joint every 3 ft., hence there is a liability of having a change of grade or of direction in the thread of the flow every 3 ft., to say nothing of the obstruction caused by the cement joints. The uncertainty with sewers laid with 3-ft. lengths is proportionately greater, and the leakage also increases with the number of joints. When one considers the various methods of construction employed, it is apparent that formula used by one engineer for sewers, built by a given contractor might produce entirely different results if the same formula were employed by another engineer superintending work to be done by another contractor. Brick sewers come in another class from pipe sewers inasmuch as they are usually constructed with more care, at a greater expense and by workmen of more experience. Again one of the most important factors in computing the size of sewers is the factor of leakage. Pipe sewers laid with 3-ft. lengths with the same degree of workmanship would necessarily have less leakage than a sewer of 2-ft. lengths as there are fewer joints. In a brick sewer, for the same reason, the leakage would be much greater.

In using the formula for the design of the size of the sewer, the anticipated leakage per capita must be added to the per capita consumption of water. Since the leakage varies with the skill of the contractor and the obstacles encountered, it is apparent that the leakage is absolutely indeterminate and no two designs can be expected to give the same results.

Some twenty miles of sewers designed for a city in New York State by one of the most eminent engineers in the profession and built under the supervision of one of the most conscientious and exacting engineers, gave a leakage of over 50,000 gal. per mile per day. The contractors, however, were generally inexperienced and they were handicapped by soil completely filled with water. Another system laid with no less rigid inspection and by a contractor of about equal experience gave a leakage of less than 3,000 gal. per mile per day. The conditions in the latter case were more favorable to sewer construction.

It is evident that in the designing of sanitary sewers where the sewage is to be carried to a disposal plant, the question of leakage is of the utmost importance, for should the leakage run to 50,000 gal. per mile per day it would be seen that it would require but 20 miles of sewers to contribute 1,000,000 gal. per day by infiltration. For an average domestic sewer system, this would require a disposal plant of nearly twice the capacity were there no leakage. It is also apparent that if the sewage is to be disposed of by pumping to any appreciable elevation, the annual charge for pumping this infiltration capitalized would be an undertaking almost as large as the construction of the pumping station.

During the season of 1905 the firm of which the writer is a member, was called in to design a comprehensive sewer system with a method of disposal for the village of Waverly, N. Y. This system embraces about 20 miles of sewers and a disposal plant consisting of septic tanks and contact beds, the idea being to turn a non-putrescible (though not necessarily clarified) effluent into Cayuta Creek just above its junction with the Susquehanna River. The flow of Cayuta Creek during the dry season is less than 3 cu. ft. per second per thousand persons at the point of proposed discharge. To empty the sewage into the creek at this point would create a nuisance which would be intolerable to the residents of the village living nearby. In fact, the sewage from the private sewers emptying near this point is not assimilated by the creek in dry weather.

For the design of the sewage disposal plant and the contributing sewers, the writer was dissatisfied with the existing methods and formula for determining the probable flow both of leakage and house sewage, and he consequently directed that gaugings be made of existing sewers and a house-to-house canvass made to determine the number of persons contributing to the same. These gaugings were made for a period of four days and consisted of hourly readings of the flow over a triangular weir. During the progress of the gaugings, a slight rainfall occurred which, as will be seen, affects the curve of flow in two different ways: First, immediately following the rainfall the curve is seen to take a decided raise which indicates that many houses have their down-spouts connected to the sewers (this is not prohibited by ordinance, as it should be); second, during the day after the rain the curve, as will be noted, holds up above the normal. This is due to the leakage or infiltration, the soil at Waverly requiring several hours for the rain water to percolate through the interstices of the soil to reach the leaky joints of the sewers. The results of these gaugings established the following rates for the combined sanitary sewage and infiltration at Waverly:

Average daily flow.........................	278,000	gal.
Persons contributing sewage.................	1,796	"
Average daily flow per capita	155	"
Minimum daily flow per capita (hour rate)..	79	"
Normal maximum daily flow (hour rate)....	194	"
Abnormal maximum daily flow (hour rate)..	459	"

The curve shows some very interesting features that are to be expected in the flow of sanitary sewage—for instance, the curve is legible enough to detect the weekly bathing hour (Saturday night); the preparation of a big dinner on Sunday and the fact that housewives begin the preparation of breakfast about an hour later than usual on Sunday morning. Wash day (Monday) morning, unfortunately, is shown only until 9 a. m., but the rapid upward tendency of the curve is significant.

The Technical School and the University.

Address Delivered by Prof. Wm. H. Burr, at the Opening Ceremonies of the 153d Academic Year at Columbia University.

During the past 400 years there has been a most significant, although gradual development in the university organization. This has been a necessary result of the evolution of knowledge. The earliest continental universities found a reason for their being in the dissemination of a system of scholastic learning which had little to do with the affairs of men. A body of learning based chiefly, if not wholly, upon certain conventional systems of abstract knowledge like the Aristotelian logic, transmitted with little or no change from the masters of antiquity, constituted essentially all they had to offer to their students. The instruction consisted almost entirely of certain exercises in this intellectual inheritance, practically unchanged through the centuries of its transmission. This mental training had essentially no relation to or bearing upon the actual things of human experience, nor had it much effect upon national life or upon any of the varied interests of the community.

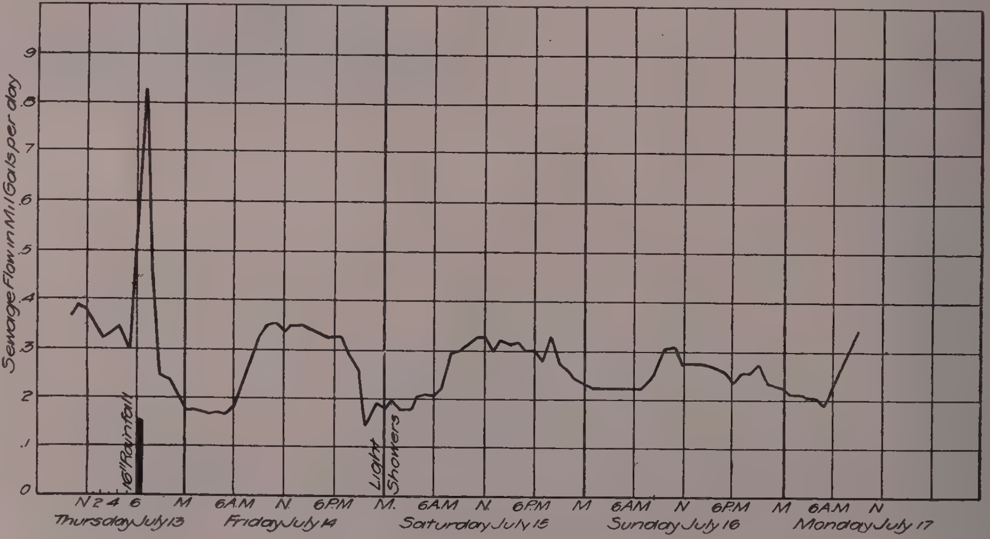


Diagram of Sewage Flow.

In the beginning of the sixteenth century, however, when the dark shadows of the Middle Ages began to disappear before the illuminating influence of a truer knowledge, a remarkable movement began in a contest which has scarcely been closed to this day. The intense struggle between Humanism and Scholasticism began in and around the German universities in the early years of the sixteenth century. The actors in this new culture rejected the old sterile instruction with merciless vigor and displaced it with systems of study touching as closely as possible the actual life of those times. It was their open purpose, in which they gloried, to treat of things as they actually existed, to get as near to the life of the community as the best knowledge would bring them; in other words, to touch human life intimately and at the greatest possible number of points.

Scarcely had the Humanistic movement reached a successful issue, before it was supplemented by the Reformation. Although this great religious upheaval was destined ultimately to aid the Humanistic movement, an intense struggle marked the first stages of their concurrent development. While the ultimate effects of these two epoch-making movements were virtually the same in their influence upon the advancement of knowledge and upon the evolution of the university, the fundamentally different characters of their two great representatives led to intellectual contests of exceeding bitterness. Fortunately, however, their efforts to advance knowledge along different lines created a common spirit of true learning, which has been the living stimulant of university life from that day until this.

During the sixteenth and seventeenth centuries the university may be said to have consisted of the philosophical and theological faculties, supplemented by the faculties of law and medicine. The subsequent extensions of the university throughout the eighteenth century, resulting from its closer contact with the things disclosed by experience and its widening influence upon all branches of human activity, were chiefly marked by the strengthening of the faculties of law and medicine.

Throughout all this period of over three centuries the philosophical faculty was predominant in its position and influence in the university. It had come to represent a body of more or less abstract instruction, covering by far the greater part of the existing field of knowledge, and it must be said, divorced largely from the real things to which it properly belonged. In the early history of universities, it constituted a sort of purveyor of privileged or aristocratic learning, ostensibly of better birth than the professional faculties of law and medicine, which had the misfortune to deal with the actualities of life on which the welfare and safety of communities no less than the rights and duties of individuals are fundamentally based. This conventional class distinction, constituting a kind of snobbery of learning, was the real influence or force so completely overcome by the movements of Humanism and the Reformation, and it has bequeathed to us the useless and senseless term "pure" science as opposed to "applied" science; as if there could be in some way a science politely distilled as an essence of learning separated from the realities with which absolutely all science whatever has to deal and without which no science whatever can exist. A mere scholastic philosophy based upon the sterility of bare convention and authority was displaced by an honest and fearless search for the real knowledge, which lies at the base of all true learning. The deadening influence of prescribed knowledge gave way to the quickening stimulus of individual power and freedom of investigation in every field of experience. All the professional schools of the university, prominent among them being the modern technical schools, are the fruitful products of this ever increasing and abundant intellectual life.

During the latter part of the eighteenth and throughout the nineteenth centuries the extensions of all branches of physical science so enlarged their fields of application that the foundations were laid of another distinct and prominent faculty. The great investigators in chemistry, in physics, in biology and in the marvelous combinations and ramifications of those and other affiliated sciences were the pioneers in the service rendered by science to the creation of the industries of the world, which have been such potent agents in the extraordinary advancement of civilization during the past 150 years. Every addition to scientific knowledge, meaning simply a closer contact with the realities of our natural environment, has supplied a corresponding field of activity for useful effort, and in just that much has enlarged the meaning and volume of life.

All these practical or useful extensions of technical knowledge have, in fact, been made possible by the technical work of the university, although many of the greatest investigators and many of those who have been most successful in enlarging useful production have received their individual stimulus and prosecuted their life work outside of the university organization. The university has been the nursery of useful scientific investigation, and the influence of its instruction has extended with an ever-increasing acceleration far beyond the limits of its immediate environment. The practice of every technical profession is founded upon precisely that quality and kind of knowledge established by investigation and by instruction at those centers of learning which only have been the originators and transmitters of useful knowledge from the earliest beginnings of science to the present day. Although there has been much scientific investigation and remarkable applications of science to human activities by individuals or in communities, to whom apparently even the meaning of university work was unknown, the fundamental principles on which the value of the subsequent technical work is wholly based will be found in practically or absolutely all cases to have germinated in the fertile soil of the university.

The initial stages of technical education took form first in the universities of Europe. The subsequent development of that educational work into complete technical faculties is found to have been practically concurrent in the universities of both Europe and America, although the former have precedence in time over the latter by comparatively short periods. These faculties have not always been known by the names of the professional practice for which it is the purpose to prepare their students, but the apparent defect in the continuity of the case is not real. In the earliest university courses of technical study, instruction was given in a substantial number of technical subjects under a faculty of broader jurisdiction than that confined to a technical profession, and in some of them that method is pursued even at the present time. Such courses of study effectively answered their purpose in the early days of the engineering and allied professions, but their administration has generally been advanced by a natural development concurrent with the growth of the professions which they have served, to remarkable groups of technical faculties of such prominence and intellectual strength and with such numbers of students as almost to dominate the true university in some cases, and even to form essentially technical universities in others.

These great technical faculties have been the direct results of the dissemination of knowledge by the university. Even the professor who has boasted that he never wittingly either learned or taught anything useful has been the servant of real learning by extending the limits of scientific knowledge, which refuses to be hindered or circumscribed by its narrowest and most erratic votaries. Wherever there has been a seat of learning, from that point has issued a quickening influence which has stimulated the growth of every form of useful activity. All the great industries on which the prosperity of every civilized nation is based have originally sprung from the small beginnings which had their initial impulse from some branch of knowledge, which was undoubtedly acquired in the first instance at the university.

So closely are all forms of knowledge related in their fundamental elements that no one of them can obtain a state of real growth without carrying others more or less with it. This elementary principle, which finds illustrations and the most conclusive proof in every field of educational experience, underlies the fundamental organization of the university, and it completely justifies the place of the technical school in the university plan. Further than that, it illuminates in a clear and instructive manner the natural development of an institution of universal learning.

The ramifications of every branch of science reach a great variety of human interests, many of which are directly affected by it, while others are more remotely touched. The full significance of every acquisition of knowledge can only be understood or even to a small degree appreciated by realizing the industrial activities or other real interests of the community which it affects. An isolated study of any one technical subject, or of any other subject, without regard to its relation to other branches of knowledge, would be excessively narrow in its results and probably as valueless as narrow, if indeed such a study be not unthinkable. The greater the number and scope of scientific or technical subjects brought within the range of instruction, the broader will be the whole amount of knowledge acquired, and the more complete and thorough will be the comprehension of any one of them. There is a limit to the number of subjects which can profitably be taken by any student in a course of proposed study, but there can be no question whatever that the instruction in any one subject will be enhanced in value in proportion to its breadth, or its reach into other and related or affiliated subjects.

The more complete the view of the field covered, the more satisfactory will be the student's work in it. In fact it may be stated that the real study of any one part of the field of knowledge consists in acquiring information relating to its effect upon other fields into which it reaches. It is impossible to conceive of any subject of scientific study as an abstraction either from other subjects or from the material elements of experience.

The bearing of all these considerations on the place of the technical school in the university is most direct and essential. In the first place, the instruction in any professional school of a technical character is an integral part of the whole body of instruction belonging to an institution of universal learning. It cannot be given so effectively anywhere else as in the organization of which it forms a part absolutely necessary for completion.

The advantages gained by a technical school in a university environment are fundamental; they touch both its technical work and the general educational training which must precede the technical in any adequate course of study of a professional character. An engineering or other technical student pursuing his work in a university system finds himself in a stimulating atmosphere of study and investigation reaching far beyond the limits of his own field. He acquires largely by incidental or even unconscious absorption a broad cultivation by constant contact with active educational work, some of which is more or less affiliated with his and some not. This association is an inspiration to a broader and a more enthusiastic view of his own work in itself, as well as a material enhancement of the value of that work by disclosing its relations to other fields of learning, all impossible to attain outside of the university. These conditions give his educational training qualities that not only strengthen and widen his subsequent professional practice but contribute most effectively to his intelligence and usefulness as an educated citizen.

More than this, the technical professions now demand of their members for the higher planes of successful practice the same general educational preparation for professional study as that required by the best law and medical schools. Without entering into a discussion as to the relative merits of the educational work done by the small college and by that forming a subordinate member of the university, it is sufficient to say that this part of a well-rounded course of professional study harmonizes completely with the university system and is, in fact, an essential element of it.

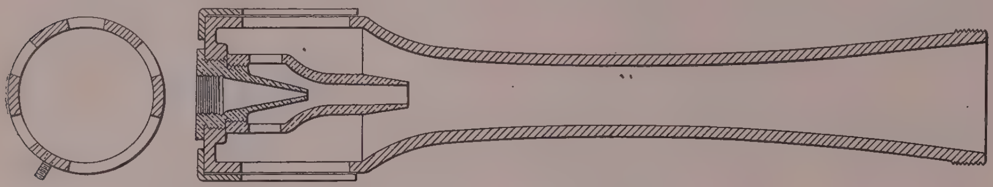
Both for technical efficiency, therefore, and for the broadest and best educational motives, the technical school is bound to find its strongest development in an environment of universal study and investigation.

The university has long since lost the character, if it ever properly had it, of a place where abstractions of learning separated from the only things which give them life are to be dispensed after the manner of instruction to men who are never to deal with the affairs of life. It has come to be an intensely practical working agent. It is effective and worthy of support only in so far as it makes itself felt in the real life of the community. If it is to be a true and real center of instruction, it is imperative that it shall carry knowledge into every useful calling, governmental, corporate, or private. The time will soon come, if indeed it is not already reached, when it only can prepare men to administer and extend in a rational and moral way the great industrial activities which at the present time form the foundation of the material prosperity of the modern world.

The true student of the technical or professional school becomes heir to a comprehensive and clear understanding of his duties and responsibilities in his relations to his fellowmen and to the community. Those duties and responsibilities present themselves to his trained mind in their real proportion. He is neither non-developed nor mal-developed in his judgment of affairs. His university training, especially in the technical school, has taught him accuracy and penetration in the analysis of any proposition confronting him, and that truth and knowledge must be sought with the directness of a plumb line. Science yields nothing but confusion to the shifty, devious and dishonest inquirer. The fundamentals of morality are the very stepping stones to technical success or professional attainment.

The opportunities offered in the administration of both public affairs and the great corporate interests of the present time, rapidly increasing in number and magnitude, create almost irresistible temptations to prostitute them to selfish gain. The realization that great power, or what has now come to be its full equivalent, great wealth, is a grave and delicate trust, to which selfish gratification in its infinite and seductive variety is abhorrent, comes most naturally and easily through sound knowledge, "the beginning of wisdom."

The correct conception of his duties gives to the professional man such a deep and true sense of his responsibilities as to render him the safest administrator for those great interests whose sinister power has already threatened both the morals and the safety of the community. Selfish gratification is a temptation to which he may or may not yield, but his inheritance from the university translates wealth to be a means of accomplishing the highest purposes of life, and saves him from that narrow, common complaisancy of wealth which is the dry rot of character.


Injector Type Gas Mixer Used with Gas Heater.

In this age of self-appointed erratic and dangerous regulators of society, when an unreasoning and destructive discontent frequently prompts to crude measures whose real purpose is a blind upheaval of the existing order of things, the intelligence and the calm balance of the university man of affairs must be the cornerstones of public safety. His trained mind, taught to analyze and to test by the records of experience no less than by the precepts of science, does not lose its poise before either the shallow plausibilities of the advocate of Utopia, or the sinister deceptions of the revolutionary reformer, or what has come to be nearly as bad, by the egotistic and blundering, although much-applauded strenuosity of the present time. It is not to be supposed for a moment that every subject of university training will issue from its halls the ideal, well-rounded citizen, but judgment must be passed upon such matters in view of the resultant tendencies. A fair and careful scrutiny of the impress made through the professional schools of the university, from the older faculties of philosophy and theology to the modern faculty of engineering, upon the broad moral, governmental, professional and business affairs of the most civilized communities of the world conclusively confirms and supports these observations.

The creative or evolutionary influence of the university upon the community is exercised chiefly, and it will ultimately be exercised entirely, through its professional faculties, its faculty of philosophy already having become essentially a professional faculty of teaching, a character which it is bound fully to assume hereafter. This is the highest and ultimately the complete mission of the university. This means with absolute certainty that professional instruction shall be given, not by closet professors, but by men who are students in the highest and best sense of the word, profound students not only of the abstract principles of their profession but of the play and power of those principles upon the affairs of men. This knowledge must be gained by taking their full part in human experience and not by withdrawing from it. Their investigations must be made largely in the practical operations of their professions. In other words, they must be men of affairs as well as students. A living and forceful quality can be given to instruction in no other way whatever but by actual contact with the things encountered in practical experience, and precisely in the relations disclosed by that experience.

Some of the professional faculties have already benefited by this quickening and energizing influence of living contact with their professions. The medical faculties are composed largely of eminent practitioners, and it is not too much to say that it would be impossible to give the requisite instruction were it otherwise. It is well known that most serious defects in the present educational administrations of the university faculties of law and engineering are due to the fact that too many instructors fail of that true development and broad training gained only by actual professional experience. It may be confidently stated that instruction in professional engineering subjects cannot now be given with the necessary breadth and efficiency without supplementing the imperatively necessary work of the study by extended practical experience. And these observations are not peculiar to the faculties to which they are applied. The time has already come when the professional faculties, and pre-eminently so those of the technical schools, must be active, living parts of their professions. There is no other way by which they can either properly discharge their own functions or become members of a university organization strengthened and equipped to meet its wide educational responsibilities, which make it one of the greatest conserving and elevating forces of the community.

The technical schools constituting the great modern professional schools of the university are integral parts of it and necessary consequences of its natural evolution. They belong to it historically and naturally. They are professional schools and professional schools not only belong to the university, they are the university.

A Faulty Location of a House, not in accordance with the plans, may cause some depreciation in the value of the property. The measure of the damage, according to the New York Supreme Court, 99 N. Y. Supp. 917, is not the expense of moving the house but the difference between the value of the property as it is and as it would be had the house been set according to plan.

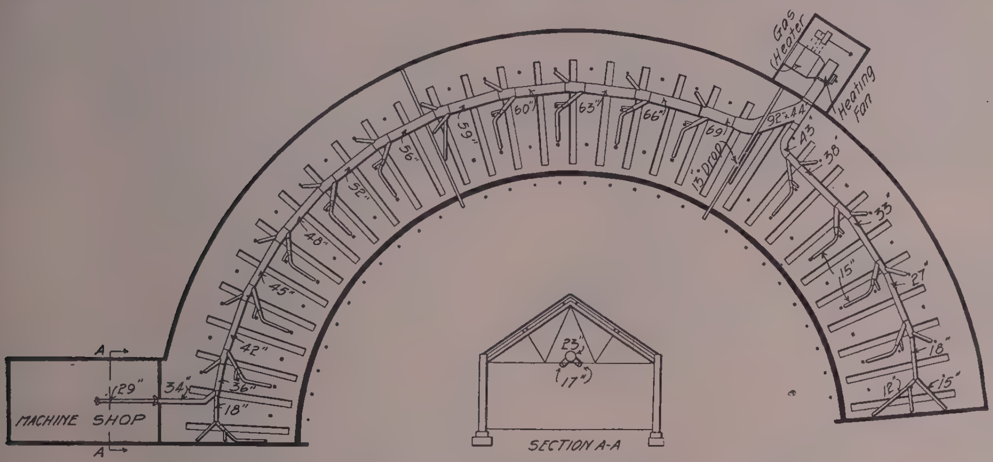
A Fan Heating System With Gas Heater.

While the indirect system of heating has come to be one of the most generally used systems of interior heating, the fact that it is usually operated in connection with steam-driven power plants has rendered the use of steam or hot water as the heating source almost universal. In sections of the country where natural gas is the common fuel, indirect heating has usually been accomplished by the use of the gas as fuel for the boiler from which steam is supplied to the fan heating coils. Recently, however, in the application of a heating system to an engine house of the Missouri, Kansas & Texas Ry. system in Kansas, departure from usual methods was made in the use of a gas heater in place of steam coils, and on account of the successful results secured the installation is an important one.

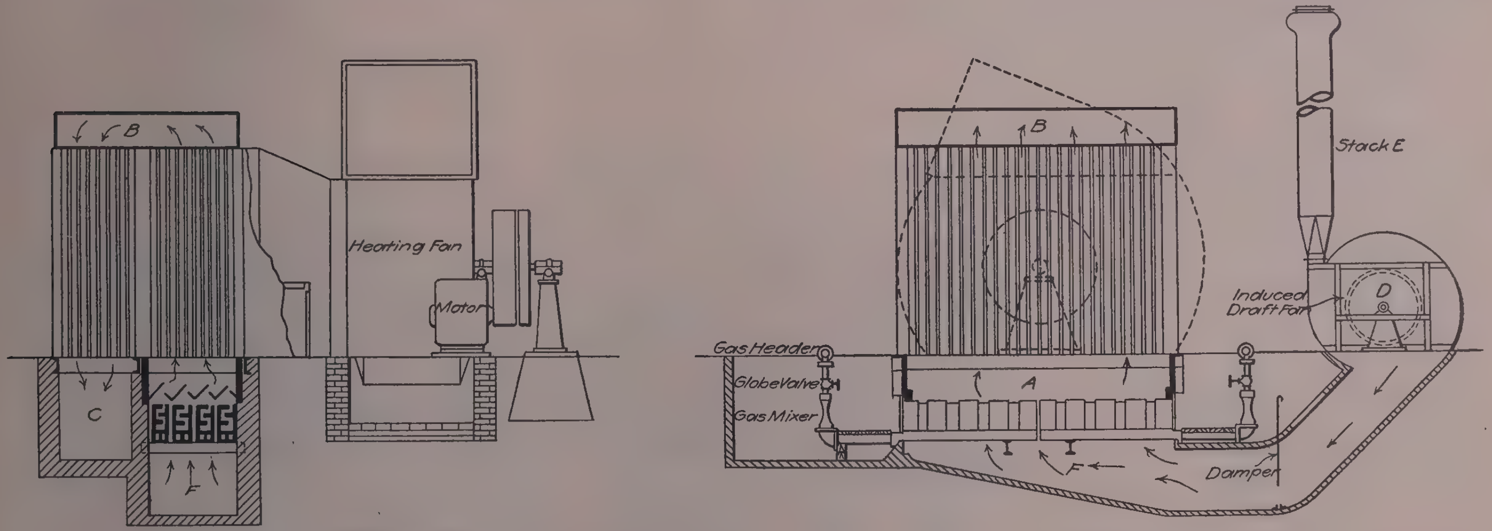
The engine house is located at Parsons, in the natural gas belt of Kansas, where, owing to its abundance, the gas is cheaper as fuel than coal. Owing to its greater convenience, also, it was decided to use the gas, but, due to the success which has attended its use in heating furnaces, the plan of installing a gas furnace and a direct air heater was considered in comparison with the more usual method of using steam coils supplied from a low-pressure gas-fired boiler. As to the relative cost of operation of the two methods, investigations indicated that, aside from a lower cost of installation, the direct air heater would be more economical. The cost with the steam boiler would, of course, depend upon the type of direct-heat furnace used, but tests made upon boilers fired by natural gas have shown that an efficiency in excess of 65 to 70 per cent. is rarely attained, which low economy is due, it is said, to the excessive amount of air that is used in the process of combustion. An equipment has been devised, however, by the Buffalo Forge Co., which company designed the plant, that proves that the efficiency of a direct-gas heater may approach 90 per cent. at its full capacity and that the efficiency will be more nearly constant under all conditions than the efficiency with the boiler plant, where, if operated below its rated capacity, it is well known that the efficiency drops rapidly; the exact opposite of this is found to be true of the gas-fired heater because the percentage of stock losses decreases at the lower capacities due to the lower temperature of the products of combustion.

View of the Gas Heating Plant at Parsons, During Construction.

The equipment as installed at Parsons is shown in the accompanying illustrations. The fan and heater equipment is located in a 28x36-ft. addition to the rear of the roundhouse, from which hot blast is distributed to the house and to the machine shop, at one end, by a system of overhead galvanized-iron ducts. The equipment consists of a multi-tubular gas heater, a hot-blast heating fan and an induced draft fan for control of the furnace draft. The two fans are belt-driven by a single electric motor, which is operated by current from the shop power and lighting system. The important feature of the equipment is the design of burner used in the heater and the scheme of combustion chamber, which together are productive of high efficiency with low furnace temperature. The operation and success of the burner is dependent upon two factors: First, burning the gas in a combustion chamber lined with fire-brick kept at a high temperature and a very small excess of air, and, second, diluting the small volume of hot gases at high temperature with a large volume of the re-circulated products of combustion at the relatively low temperature of about 400° Fahr., giving a resultant temperature not to exceed 1,200° Fahr.



Arrangement of Heating Ducts at the Parsons Roundhouse.



Details of the Gas Furnace, Air Heater and Hot Blast Fan Equipment.

The heater construction is well shown in the accompanying drawings. The apparatus consists in general of a bank of 4-in. vertical boiler flues expanded at the top and bottom into wrought-iron tube sheets of boiler plate. Beneath the tubes there is a space below the floor line which is divided into two compartments. The first compartment, *A*, comprises the furnace proper, where the gas is burned under special conditions, and the other portion, *C*, underneath the tubes, is an exhaust chamber for the burned gases. Above the tubes is located a breeching or connection, *B*, which is provided with a removable sectional cover to allow for cleaning and inspection of the tubes. The path of the hot gases is thus upward from the furnace, *A* to chamber *B*, and thence downward through the tubes to chamber *C*, from which the products of combustion are handled by the induced-draft exhaust fan at *D*. The bank of tubes is enclosed by a sheet-metal casing through which the air for heating purposes is drawn by the motor-driven steel-plate heating fan. This fan delivers the air heated to a temperature of about 170° Fahr. through galvanized-iron ducts to the engine house as shown.

Four combustion chambers, each 9 in. wide, and running parallel with the length of the furnace, are provided and are fed by 16 gas mixers. Each combustion chamber is supported upon a double-slotted cast-iron burner, and the interiors of the combustion chambers are provided with fire-brick checker work, which, becoming incandescent, provides for the complete combustion of the mixture of gas and air, before it leaves this chamber and passes up into the flues of the heater. The cooler products of combustion are thence drawn into the induced-draft fan and are partly discharged through the small vertical stack, but by far the greater portion of them are returned to the chamber, *F*, under the burners. This gas, returned, mixes with the products of combustion above the burners, aided by cast-iron baffle plates, but the dilution with the cooler flue gas does not disturb the combustion, as this is complete when this dilution occurs.

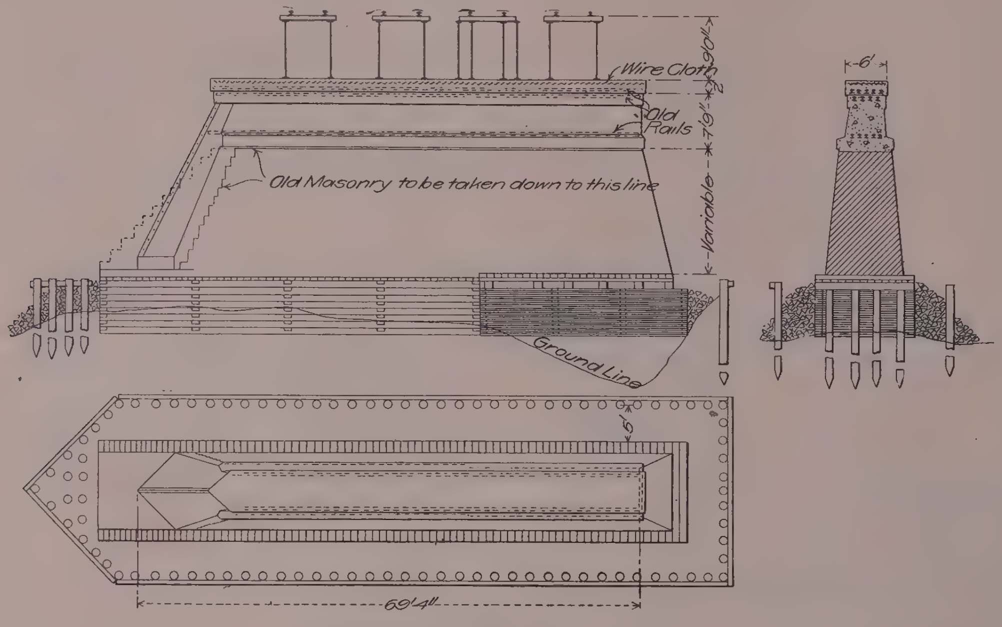
The gas mixers supplying the burners are also of special construction, being designed to work with the pressures from 10 to 20 lb. Due to the type of burner in use the mixers must supply fuel with a quantity of air slightly in excess of that required for perfect combustion, while ordinarily burners use a mixture of gas and air containing gas in excess—so that combustion is made complete by the introduction of additional air into the furnace to supply the deficiency. The difficulties experienced in attempting to burn a mixture containing the full quantity of air are due to the tendency of the flame to strike back through the burner openings unless the velocity of the gas be sufficiently high. Associated with this is the fact that unless the combustion takes place at a very high temperature the flame is very easily extinguished. For these reasons the "injector" type of gas mixer, shown in the drawings, was designed, being a compound nozzle which supplies a relatively large amount of air to the burner. A test was made upon the burner in which the fuel was supplied at a pressure of slightly over ½-in. water pressure, and it was found that, when the flames just disappeared at the top of the fire brick chamber (regulated by adjusting the air ports), the combustion was practically perfect.

Analysis of the flue gas showed from one to two per cent. of oxygen present, one analysis showing as low as one-half of one per cent. While theoretically the temperature of such combustion would be 5,000 or 6,000° Fahr., but little more than one-half of this was attained in the combustion chamber, due to the fact that the thin fire-brick walls are surrounded on the outside by the cooler flue gases which had been re-circulated by the induced-draft fan at high velocity. All portions of the cast-iron burners are outside of the combustion chamber save the top, which is amply protected by fire brick. The fire-brick lining is of the best grade and capable of withstanding temperatures up to 4,000° Fahr.

As to the efficiency of the burner, it will be seen that, though a large volume of the flue gases is re-circulated to maintain a low temperature and in that way secure an efficient transfer of heat from the products of combustion to the air supplied to the building, the volume of gases discharged as useless equals the fresh air supplied to insure perfect combustion. Due to the fact that the furnace is of the internally-fired type, radiation is utilized and actual efficiency would closely approximate the theoretical as calculated from the furnace temperatures. Since 9 cu. ft. of air and 1 cu. ft. of gas is required in the production of 1,000 B.t.u., there will be lost nearly 60 B.t.u. with the temperature of the waste gases at 400° Fahr. These results correspond to an efficiency of 94 per cent.

The use of the gas furnace with producer gas would, from this, appear to be highly practicable, as the average producers on the market insure an efficiency of from 65 to 70 per cent. when using soft coal, which allows a combined efficiency of 60 per cent.; the average boiler giving a maximum efficiency of 65 per cent. would afford only 50 to 55 per cent. under the variable conditions of a heating plant. This leaves a wide margin in favor of using a gas-fired furnace for heating in plants where steam is not used as the motive power and shows that the gas heater with producer gas may be operated quite as economically as a steam heating system.

In the Parsons roundhouse, which contains 32 stalls and also a machine shop, it was computed that about 8,000,000 B.t.u. per hour would be required for heating to 65° Fahr. in zero weather. It was shown that with a steam plant an initial fuel consumption equivalent to 12,000,000 B.t.u. would have had to be furnished per hour, while with the above heater 9,000,000 B.t.u. per hour is sufficient. However, under average conditions, about one-half of the above heating valves are required, which allows an average saving of 1,500,000 B.t.u. per hour and a maximum economy of 3,000,000 B.t.u. per hour. The average is equivalent to about 1,500 cu. ft. of gas per hour, which at 12 cents per thousand cubic feet permits a saving of 18 cents per hour, or $3.60 per 24-hr. day. In addition must be counted the saving in labor and attention required. An estimate of $400 yearly is made, which is 8 per cent. on the cost of the equipment.



Cofferdam and Extension of Old Piers.

Contractors for Street Improvements in Scranton labor under special difficulties, according to City Engineer Henry Jifkins, who made the following comments some time ago in an address before the local Engineers' Club: "Contractors bidding on a city work are obliged, in order to protect themselves from loss, to take into consideration the fact that the monthly estimates of work done given by the engineer are not honored in cash, but only that amount of cash which has been paid in by the abutting property holders at that date can be given to the contractor, and the balance (less 10 per cent. retained) he must take in street improvement bonds, which the local banks will not negotiate and which he is compelled to hawk around the country to realize on, and then at a discount. Had we the means of paying cash for our city work, we would have the same discount or reduction price bid as everybody else has for cash. Under our laws, also, the contractors must give a bond of one-half the contract price. This again is burdensome to them, and they include the cost of this item in their bid."

Reconstructing the Piers of a Double-Track Railroad Bridge.

The New York Central & Hudson River R. R. originally crossed the Mohawk River at Schenectady, N. Y., on a double-track bridge, 723 ft. long, which was comprised of ten nearly equal deck lattice girder spans supported on masonry piers with an average height of 5 ft. above high water and 30 ft. below high water. Several years after it was built the bridge was enlarged by the addition of two more tracks. The new girders parallel to the old ones were supported on continuations of the old piers extended downstream and built like the old portions, except that the crib work was made of somewhat different construction. The piles were capped longitudinally just below low water level, with a deck made with one solid course of transverse 6-in. planks and surrounded by a crib of 3-in. planks laid flat and interlaced, while on the old portion the piles were not capped, but were surrounded by a crib of hewn timbers, and topped with a platform of 6-in. planking, laid transversely and supported on pile tops or gravel filling as they happened to come, and resting on the edges of the cribs. The old piers were not in any way protected except by the cribbing mentioned and after a time were somewhat undermined by the erosion of the bottom which was sufficient to cause perceptible settlement.

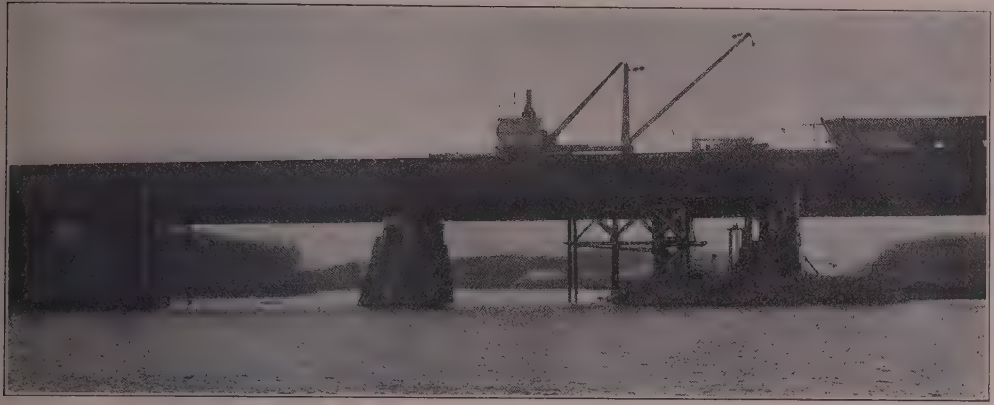
The recent abolition of grade crossings by the New York Central & Hudson River R. R. in Schenectady required the super-structure of this bridge to be raised about 5 ft. at the east end, and 3 ft. at the west end, the tracks being changed from level to a 0.35 per cent. grade, and when this work was done the opportunity was improved for reconstructing the piers at the same time that they were made higher to provide for the new grade. Provision was also made for the removal of the second and third piers from the east end of the bridge and the construction of larger new piers in place of the first and fourth piers so as to provide a single span 200 ft. clear opening for the barge canal that is to be made in the river at this point. This work, however, will not be executed immediately and the old piers are still in service for this part of the bridge.

For the remainder of the bridge, the piers originally numbered 5, 6, 7, 8 and 9, are being reconstructed and the entire superstructure has been raised to the required grade. Traffic was abandoned on tracks 1 and 2, and girders carrying these tracks raised by means of steam cranes and jacks to final grade and supported on timber cribbing. Double transverse rows of piles on each side of old pier 6 were driven from the tracks, through the bridge floor.

The pairs of transverse bents were braced together longitudinally and transversely to form towers with transverse caps seated on the pile tops and wedged up against the bottom flanges of the girders so as to take the full weight of the latter, and release the old pier which was removed down to the water's edge as shown in the accompanying illustration taken from a photograph looking north, December 2, 1905. A cofferdam made with 12-in. triple-lapped wooden piles was driven around the old pier enclosing the falsework towers, and the submerged masonry and old cribs were removed. The most faulty of the old piles were pulled and replaced with new piles and additional piles were driven and a mass of concrete 12 in. thick was placed around them flush with the upper ends, which had been accurately sawed in the same horizontal plane. Above this level a 3-ft. battered layer of concrete was carried up to the base of the pier shaft and was reinforced by longitudinal and transverse tiers of old rails from 10 to 12 in. apart on centers. They were laid to break joints and were spliced with two angle bars. On this

Near View of Falsework Towers Supporting Girders During Construction.

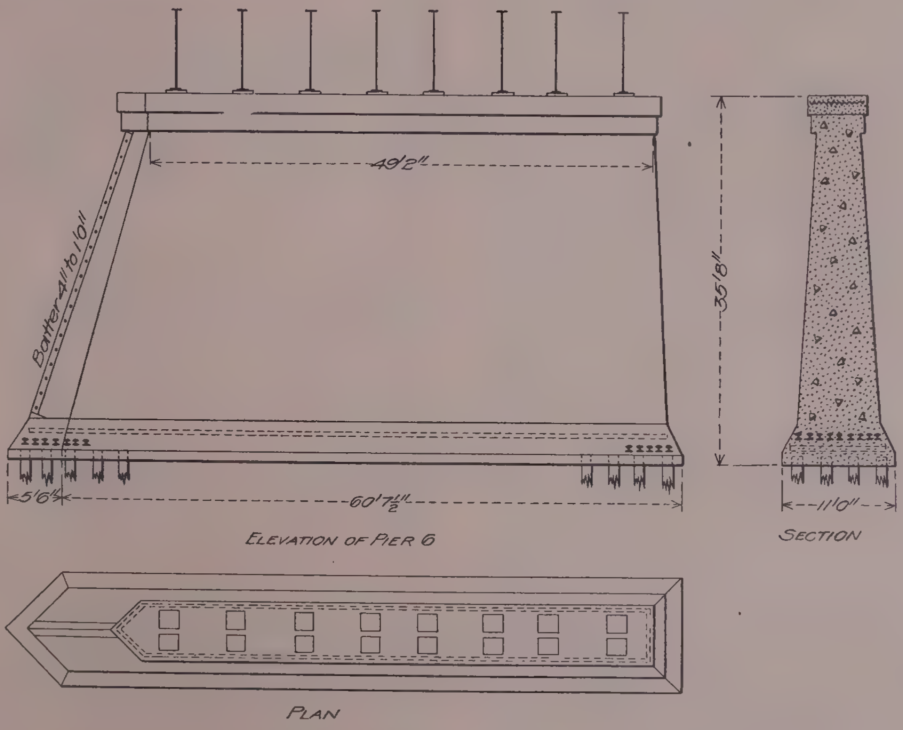
course was built the pier shaft 30 ft. high with the two long sides and the down-stream end battered 3 to 48 and made with 1:3:6 Portland cement concrete. The up-stream end of the pier was battered 1:6 and pointed 90 deg. to act as an ice breaker. Its edge was protected with an 8x8x¾-in. breakwater angle secured with countersunk bolts bedded in the concrete. The shaft is finished with two projecting courses, the upper one made with 1:1:2 concrete and reinforced near the upper surface with a continuous sheet of 3x8-in. mesh, Clinton galvanized wire cloth made with Nos. 8 and 10 wires.



Girders Supported on Falsework Towers During Construction.

Tracks 1 and 2 of the bridge were devoted entirely to construction purposes. On them concrete was delivered by means of dump cars from a Ransome concrete mixer installed on shore and discharged through a chute.

The cofferdam as planned for the construction of old pier six, was 70 ft. long and 15½ ft. wide in the clear inside and was made with 12-in. sheet piling driven against 10x10-in. outside rangers bolted at low-water level to guide piles 8 ft. apart. The bracing consisted of three tiers of inside rangers and transverse struts 8 ft. apart in the planes of the outside guide piles, all timber being 10 x 10 in. Inside the cofferdam a row of 3-in. tongue and groove sheet piling inclined slightly outwards was to be driven to a depth of 10 ft. below the bottom of the river, thus penetrating a little farther than the sheet piles and reaching almost under their feet. The plan could not be followed exactly in construction on account of riprap encountered in driving and a much larger dam was constructed in order to avoid the riprap. The cofferdam was removed after the construction of the pier. The ends of the cofferdam were braced at the center point by pairs of diagonal struts mortised into the side rangers at the ends of the first transverse struts. As the construction of the new pier progressed, the cofferdam braces were of course replaced by short braces from both sides bearing against the concrete moulds.



New Reinforced Concrete Pier with Pile Footing.

In demolishing the old pier the masonry was found much better than had been anticipated, and as a series of observations recorded for several years did not show any recent increase in the settlement or displacement of the remaining old piers, it was decided that it was unnecessary to wholly remove them and a large part of the original masonry is retained in the other reconstructed piers. A careful examination showed that the cribs under the old parts of the piers had been undermined, as indicated in the accompanying general drawing of piers 5, 7, 8 and 9. A row of protecting piles is driven to enclose the foundations and the space between them and the old footing is filled with riprap stone to protect the surface of the ground and prevent any future scour. Falsework towers are built on each side of each pier, similar to those shown in the picture of pier six, and support the ends of the adjacent spans while the old masonry is cut down about 3 ft. to the bottom of the coping courses and the up-stream ends racked off to the deck of the crib. No cofferdams were required in this work, the lower portions of new concrete starkwaters being deposited on the cribs under water. The tops and ends of the piers are rebuilt with 1:3:6 concrete up to the level of the new copings which are made 1:1:2. A tier of longitudinal reinforcement rails is bedded in the pier shaft just below the coping and another tier is bedded in the coping which is further reinforced by a layer of Clinton wire cloth. Old piers 5, 7, 8, 9 are being thus reconstructed, some of them having been completed, and similar work has been done on the abutments which with their wing walls were topped out with concrete and protected by riprap at the bottom, having a slope of 1½:1.

Girders Blocked Up on Reconstructed Pier.

After tracks 1 and 2 were raised to final grade and pier 6 reconstructed traffic was turned on these tracks; tracks 3 and 4 were abandoned for traffic, raised and used for construction tracks. The work was planned under the direction of Mr. W. J. Wilgus, vice-president; Mr. C. J. Parker, principal assistant engineer, and Mr. A. W. Carpenter, engineer of bridges, and will be executed entirely by the railroad company's forces under Mr. G. W. Vaughan, engineer of maintenance of way, and Mr. C. E. Lindsay, division engineer.

Heating and Ventilating Schoolhouses.

By Charles L. Hubbard.

The heating and ventilating system of a modern school building has now become a matter of as much importance as the construction of the building itself, and its design should be laid out with as much care as that of the architect. The following data is based on many years of practical experience in this particular line of work and may be easily adapted to almost any building: The first point to be considered is, of course, the selection of a suitable system, and this is usually determined by the cost of installation and the size and location of the building. Assuming that a selection has been made, the principal points to be considered in laying out and proportioning the different parts of the apparatus will be described in some detail.

Furnace Heating.—For school buildings of small size, the furnace system is simple, convenient and generally effective. Its use is confined as a general rule to buildings having from 2 to 4 rooms, although furnaces are sometimes used for 8-room buildings. One furnace is not commonly made to warm more than two classrooms, as the warm-air pipes connecting the furnace with the flues must be short, to obtain the best results.

Like all systems which depend on natural circulation, the supply and removal of air is considerably affected by changes in the outside temperature and by winds. The furnaces used for school-house warming are usually built of cast iron, this material being durable, and easily made to present large and effective heating-surfaces. To adapt the larger sizes of house-heating furnaces to schools, a much larger space must be provided between the body and casing, to permit a sufficient volume of air to pass to the rooms. The free area of the passage should be sufficient to allow a velocity of about 400 ft. per minute.

The size of furnace is based upon the heat loss by conduction through walls and windows plus that required for ventilation. With more regular and skilful attendance, it is safe to assume a higher rate of combustion in school-house furnaces than in those used for warming dwelling houses. Allowing a maximum combustion of 6 lb. of coal per hour per square foot of grate, and assuming that 8,000 B. t. u. per pound of coal are taken up by the air passing over the furnace, we have 6 × 8,000 = 48,000 B. t. u. furnished per hour per square foot of grate. Therefore, if the total B. t. u. required for both warming and ventilation be divided by 48,000 it will give the necessary grate-area in square feet. It has been found in practice that a furnace with a fire-pot 32 in. in diameter, and having ample heating-surface, will heat two 50-pupil rooms in zero weather.

The velocity of the warm air within the uptake flues depends upon their height and the difference in temperature between the warm air within the flues and the cold air outside. The action of the wind also affects the velocity of air flow. It has been found by experience that flues having sectional areas of about 6 sq. ft. for first-floor rooms, 5 for the second-floor, and 4½ for the third, will be of ample size for standard classrooms seating from 40 to 50 pupils in primary and grammar schools. These sizes may be used for both furnace and indirect gravity steam heating.

In mild damp weather, the air-supply will fall somewhat below the standard desired; but if the flues are made much larger they will furnish more air than can be heated in cold and windy weather. The cold-air supply duct may be made three-quarters the size of all the warm-air flues, if free from bends, or the full size, if obstructed in any way. Each furnace should, if possible, receive air from two sides of the building, preferably the north and south, or the northwest and southeast. Each duct should be of sufficient size to supply the full amount of air required, and should be provided with an air-check similar to that shown in Fig. 1, made up of flaps of duck or light canvas, closing against a screen of wire netting. To make the system more complete, mixing-dampers may be placed in the warm-air flues. A typical arrangement of furnace, air-ways and dampers is shown in diagram in Fig. 2.

The vent-flues may be made 5 sq. ft. for the first floor and 6 for the second and third. They may be arranged in banks and carried through the roof in the form of large chimneys, or may be carried to the attic space and there gathered by means of galvanized-iron ducts connecting with roof vents of wood or copper construction. The former arrangement, however, is to be preferred, when it can be provided for. All roof vents should extend well above the ridge of the building in order to prevent down draughts caused by the air currents striking the roof and being deflected down the flues. Flues starting above the basement should in general be covered with a hood of some form to keep the snow and rain from falling into them. Where a hood is used, the free opening under it should be made twice the area of the flue. This is done because in case of winds the entire discharge from the flue is in one direction and must pass through only two of the external side-openings under the hood. Roof vents starting at the attic floor, or above, should be provided at the bottom with water-tight pans of copper or galvanized-iron, with suitable drains, to prevent rain or melting snow from reaching the ceiling below. All vent-flues through the roof should be provided with dampers for closing when school is not in session. In order to make the vent-flues draw sufficiently in mild or heavy weather, it is necessary to provide some means for warming the air within them to a temperature somewhat above that of the rooms with which they connect. This may be done by placing a small stove, made especially for this purpose, at the base of each flue. If this is done, it is necessary to carry the air down and connect with the flue just below the stove.

A much better method, and one equally effective, is to use a wrought-iron chimney-stack for the furnace and carry it up between two vent-flues, as shown in section in Fig. 3. If a separate furnace is used for each two rooms, this arrangement may be used in each case. The inlet and outlet openings from the rooms into the flues are commonly provided with grilles of iron wire, having a mesh of 2 to 2½ in. Both flat and square wire are used for this purpose, the weight of wire depending upon the size of opening. For ordinary work, 5/16-in. flat wire or ⅛ to 3/16-in. square wire may be used, set in light channel-iron frames. In the best class of work, flanges are riveted to the channels and the grilles screwed to wood grounds or frames.

Dampers are commonly placed back of the inlet grille for closing in case the room is not in use.

Similar dampers should be provided for the vents, although curtains with rolls and pull cords, similar to the ordinary window shade, are often used for this purpose. The use of dampers at the vent openings is for night closing and for regulation in the case of temporary down-drafts or excessive ventilation during high winds. Shut-off dampers should be placed in all cold-air inlets, and doors opening from the basement into the cold-air box should be provided for use at night or when the school is not in session.

Indirect Gravity System.—The indirect gravity system of steam heating comes next in cost of installation. This is adapted to larger buildings than furnace heating because a stack or heater may be placed at the base of each flue and a single boiler made to supply them all, thus doing away with the necessity of carrying several fires. Heating or aspirating coils may be used in place of stoves in the vent flues, thus simplifying the system still more.

The gravity system has the fault of not supplying a uniform quantity of air under all conditions of outside temperature, the same as a furnace, but when properly arranged may be made to give quite satisfactory results during the greater part of the heating season. The greatest care should be taken to provide an abundant supply of cold air to the heaters, and ducts should be arranged for taking it from at least two sides of the building, or, if possible, from all four sides. When it is taken from four sides, each inlet should be made large enough to supply one-half the amount, or in other words, any two should give the total quantity required.

It is often possible to arrange the flues in

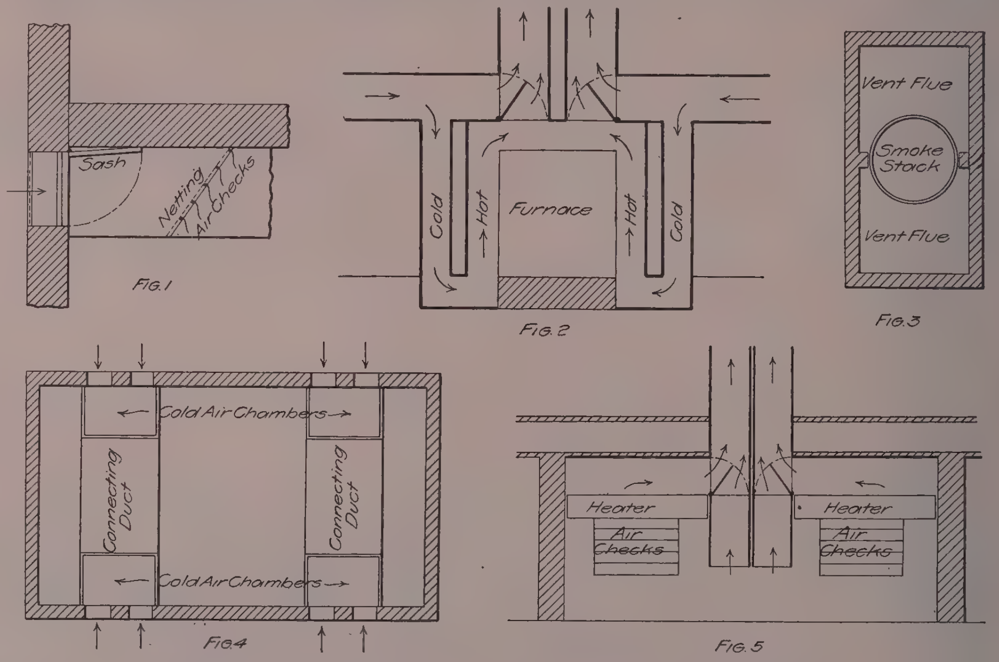


Fig. 1 Fig. 2 Fig. 3 Fig. 4 Fig. 5

Various Arrangements of Heating and Ventilating Apparatus.

groups so that all of the heating stacks may be placed in two or more cold-air chambers, depending upon the size of the building. A cold-air trunk-line may be run through the center of the building, connecting with the outside on all four sides, and having branches supplying each cold-air chamber. Sometimes the stacks may be placed as shown in Fig. 4, each cold-air room having an outside inlet window and, in addition, a cross-connection with the air-chamber upon the opposite side of the building.

The inlet to each cold-air chamber should be of sufficient size to supply both stacks. Fig. 5 shows a typical arrangement for a cold-air chamber with heaters supplying four rooms, the two flues not shown being duplicates of those in the cut. The cold air is admitted through inlet windows as shown in Fig. 6. The sashes are hinged at the top and close against frames set at a slight angle from the vertical, so that their weight will cause them to shut tightly without the use of levers or weights. A galvanized-iron casing with cloth air-checks should be provided to prevent back-draughts from carrying the air from the chamber out of doors.

The sashes may be operated by chain-and-pulley attachments as shown. Mixing-dampers are arranged in the flue as indicated, and are operated from the rooms with which the flues connect. The chains should be of good size and run over full guarded pulleys not less than 3 in. in diameter. They should pass into the rooms 3 or 4 ft. above the floor through catch plates marked to indicate their use. Regulating dampers should be placed in the flues at some point above the mixing-dampers, for regulating the flow of air to the different rooms.

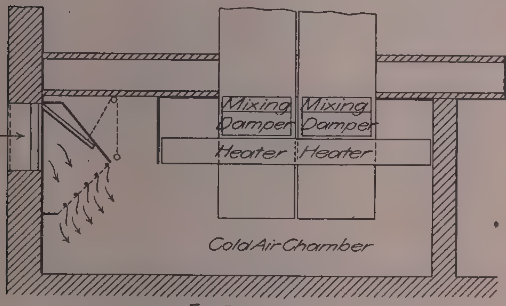


Fig. 6

Arrangement of Air Inlet Window.

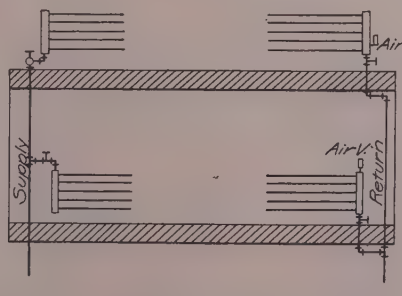


Fig. 7

Steam Connections for School Rooms.

Special care should be taken to make the mixing-dampers tight-closing, and they should be stiffened with light angle or tee iron in order to hold them in shape.

The opening into the flue from the hot-air space over the heater should be practically the full size of the flue.

One of the principal objections to a mixing-damper is its failure to thoroughly mix the currents of hot and cold air before they reach the register. In the case of schoolhouse work, the height of the flues, even to the first floor, is sufficient to overcome this to a considerable extent, especially if the dampers are arranged so that the cold air ascends at the back of the flue and is delivered at the top of the register. In this case the warm air entering at the bottom of the register tends to rise, and the cold air at the top to fall, thus mixing the two currents as they are delivered into the room. The flues may be made either of galvanized-iron or of brick; the former is preferable on account of its smooth surface, but if brick flues are smoothly plastered they may be made to give satisfactory results, and are somewhat more durable than iron.

Cast-iron pin-radiators are particularly adapted to this class of work. The "School Pin," having a section about 10 in. in depth and rated at 15 sq. ft. of heating surface is used quite extensively by some engineers. The "Utica Pin" has been found to be one of the most satisfactory patterns, in the experience of the writer. The sections are connected at alternate ends so that the flow of steam is positive through each section of the entire stack. The sections are rated at 12 sq. ft. of heating-surface each, and are about 7 in. in depth. The free air-space between the sections of both patterns is a little over 60 sq. in. An efficiency of 800 B. t. u. may be safely counted upon in zero weather with radiators of the above form. A standard corner class-room, seating 50 pupils and having the usual proportion of glass surface, requires from 20,000 to 30,000 B. t. u. per hour for warming, and about 150,000 B. t. u. for ventilating purposes in zero weather, making a total of 180,000 B. t. u., and 180,000 ÷ 800 = 225 sq. ft. of heating-surface required. Stacks containing from 220 to 240 sq. ft. of surface for southerly rooms and from 240 to 260 for those having a northerly exposure have been found ample for ordinary conditions in zero weather. The stack for each room should be divided into two groups in the proportion of 1 to 2, with valves in the supply and return so that the surface may be partly proportioned to the outside temperature. More accurate adjustment may be obtained by the use of the mixing-damper which is under the control of the teacher.

Where mixing-dampers are employed it is well to hang dial thermometers at the center of the inlet grilles to indicate the temperature of the entering air. A little experience will then enable one to tell what temperature of air is necessary to warm the room under different outside conditions. Without this, the damper is very apt to be thrown wide open for either hot or cold air as the immediate requirements may indicate, with the result of either overheating the room on the one hand, or of producing draughts and reducing the air-supply below the normal, on the other. For the best results, a mixing damper should be set in an intermediate position, so that the mixture of warm and cool air will be in the right proportion to maintain an even temperature within the room. The vent-flues should be provided with steam coils for use in mild weather and also in cool weather until an outward flow is well established. It has been found by experience that an efficient coil having from 30 to 40 sq. ft. of heating-surface is sufficient for the vent of an ordinary sized school-room. One of the best forms of heater for this purpose is made up of Nason tubes screwed into a cast-iron base and placed in an inclined position within the flue just above the vent opening from the room. Each heater should have a separate supply pipe running up from the basement; these are usually placed upon a separate line of piping so that the heaters may be used when the rest of the building is shut off.

A separate boiler of small size for supplying these heaters is often provided for use in spring and fall before the heating-boilers are fired up. Especial care must be taken to locate the air-valves upon the vent-flue heaters at points where they can be reached for adjustment. A good arrangement is to bring down a small pipe from each heater and place the air-valves just back of the grille in such a manner that they may be easily reached by means of a screw-driver or key. In any system of indirect heating, provision should be made for air rotation by doors opening from the basement into the cold-air chambers. At night or when school is not in session the outside cold-air windows should be closed and the rotation doors opened. Doors from class-rooms into corridors, and from corridors into basement stairways, should also be opened to allow a complete rotation of air through the heaters for warming without ventilation.

Foot-warmers, so-called, should be placed under the first floor corridor, near the entrances. These consist of indirect stacks containing from 80 to 100 sq. ft. of heating-surface placed at the basement ceiling with large registers above them. A long narrow register, from 12 to 18 in. in width, will accommodate more pupils at the same time than one of the same area more nearly square.

These heaters are sometimes made to take their air directly from the basement through large openings in the bottoms of the casings, but it is better to connect them with the outside air-supply and thus furnish fresh air to the corridors. Small rooms, such as teachers' rooms, toilet and coat rooms, are best heated by direct radiation, but should be provided with vent-flues. The radiator sizes may be computed by any of the standard methods in common use. In basement rooms it is usually necessary to place the heating coils near the ceiling in order to bring them above the waterline of the boiler. When this is done it is necessary to increase the surface from 30 to 50 per cent. above that computed, as coils placed in this position are less efficient than when near the floor.

One of the disadvantages of indirect heating for school-house work is the delivery of all the heat to the room from a single point, and this not always in a position to give the best results. The outer walls are thus left unwarmed, except as the heat is diffused throughout the room by air currents. When there is considerable glass surface, as in most of our modern school-rooms, draughts and currents of cold air are frequently found along the outside walls. A better arrangement, although somewhat more costly, is the use of indirect heaters for warming the air needed for ventilation, and the placing of direct radiation in the rooms for heating purposes. The general construction of the indirect stacks and flues may be the same, but the heating-surface can be reduced, as the air in this case must be raised only to 70° or 75° Fahr. in zero weather; the heat to offset that lost by conduction through walls, and so forth, being provided by the direct surface. The mixing dampers should be retained, but the temperature of the rooms may be regulated by opening or closing the steam-valves on the direct coils, which may be done either by hand or automatically.

The indirect stacks, when used for ventilation only, should contain about 200 sq. ft. of heating surface for each room. If we assume 50 pupils per room, with an air-supply of 40 cu. ft. per minute each, we shall have 50 × 40 × 60 = 120,000 cu. ft. per hour and (120,000 × 70) ÷ 55 = 152,000 B. t. u., in round numbers, and 152,000 ÷ 800 = 190 sq. ft. of heating-surface required.

It is evident that for much of the time this amount of heating-surface will be sufficient for both warming and ventilating and, if mixing-dampers are provided, the direct surface will be needed only in the coldest weather and may be operated by hand. Where the first cost must be kept as low as possible, this arrangement may be used, but if the most satisfactory results are desired at an increased cost, the mixing-dampers may be used for regulating the temperature of the ventilating air only, and automatic control applied to the direct coils. In addition to this, the indirect stacks should be divided into sections and valved as already described.

The direct surface may be computed by usual methods or by the following simple rule which has been found to give satisfactory results in a large number of buildings of this class: Divide the outside wall surface by 12 and the glass surface by 5; add the quotients, and the results will be the square feet of heating-surface required for wall coils. If cast-iron radiators are to be used in any of the rooms the surface computed by the above rule should be multiplied by 1.3.

These sizes are for rooms having a southern exposure; for other exposures, multiply by the factors already given for this purpose. If the building has a cold attic, the heating-surface in rooms on the upper floor should be increased about 20 per cent. Where a building is in a very exposed location, or where the temperature frequently drops below zero, the factors 10 and 4 may be used in place of 12 and 5. The direct radiation is best made up in the form of circulation coils and placed along the outer walls beneath the windows. This supplies the heat where most needed, and does away with the tendency to draughts. Where direct radiation is used, the quantity of heat supplied is not affected by varying wind conditions, as is the case in indirect heating. Although the air-supply may be reduced at times, the heat quantity is not changed. Circulation coils are usually made up of 1¼-in. pipe screwed into branch tees and supported upon hook-plates attached to the wall. It is common in school-house work to run pipes around the two outside walls in corner rooms, making the steam connection at one end and the return at the other. Coils of this form should have a grade of about 1 in. in 20 ft. toward the return end in order to secure proper drainage and quietness of operation.

As the class-rooms are regularly superposed on the different floors, supply risers may be carried up and the coils on each floor supplied from the same riser. The returns are sometimes connected with a common return in a similar manner. Where this is done they should be dropped through the floor and the connection made with the vertical drop at the ceiling of the room below. A check-valve should be placed in each connection to prevent the steam from one coil backing into another through the return when it is first turned on. This method of connection and the proper location of air-valve are shown in Fig. 7. A better arrangement is to carry a separate ¾-in. return from each coil to the basement, and connect with the main horizontal return below the water-line of the boiler; this seals each connection and makes each coil independent of the others. When the connections are made in this manner, the air-valves may be placed in the return drops just below the basement ceiling instead of on the coil.

Sometimes the rooms are so arranged that the heating-surface must all be placed upon a single wall. In this case a "return bend" or "trombone" coil should be used instead of a branch coil, to allow for the expansion of the pipes. Overhead coils in basement rooms are usually of the "miter" form laid on the side and suspended about a foot below the ceiling; they are less efficient than when placed nearer the floor, as the warm air stays at the ceiling and the lower part of the room is likely to remain cold. They are only used when wall-coils or radiators would be in the way of fixtures, or when they would come below the waterline of the boiler if placed near the floor.

Fan System.—The most satisfactory method of ventilating buildings having six or more rooms is by means of a fan or blower.

With this system the air-supply is practically constant under all usual conditions of outside temperature and wind action. This gives it a decided advantage over natural or gravity methods which are affected to a greater or less degree by outside conditions as already stated. In the usual or plenum method, the air is forced into the building after being passed through a heater for raising it to the desired temperature. The heater is usually made up in sections so that steam may be admitted to or shut off from any section independently of the others, and the temperature of the air regulated in this manner. Sometimes a by-pass damper is employed, so that part of the air will pass through the heater and part around or over it; in this way the proportions of cold and heated air may be so adjusted as to give the required temperature to the air entering the rooms. These forms of regulation are common where a blower is used for warming a single room, as in the case of a church or hall; but where several rooms are to be warmed, as in a school-house, it is customary to use the main or primary heater at the blower for warming the air to a given temperature, somewhat below that which is actually required, and to supplement this by placing secondary coils or heaters at the bases of the different flues, or by the use of direct radiation in the rooms. By means of these arrangements the temperature of each room can be regulated independently of the others. The so-called double-duct system is sometimes employed for this purpose. In this case two ducts are carried to the base of each flue, one conveying hot air and the other cool or tempered air, and a mixing-damper placed at that point for regulating the quantity of each for producing the desired temperature.

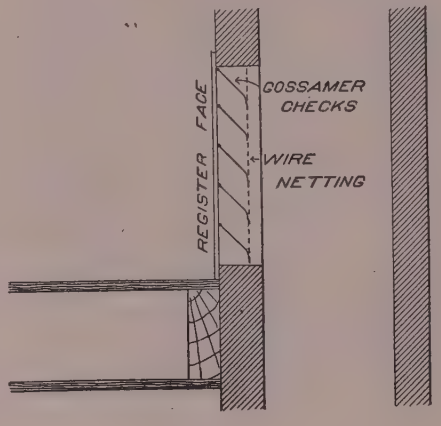


FIG. 8

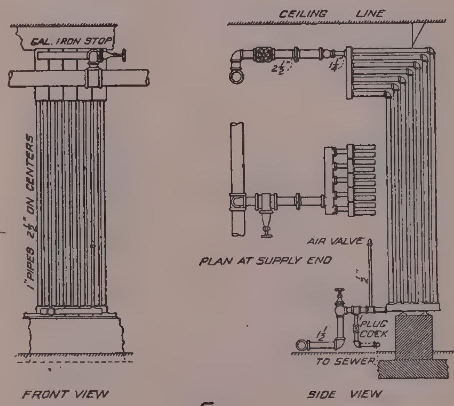


FIG. 9

Air Checks; Limited Space Heater.

The volume of air which a given fan will deliver depends upon the speed at which it is run and the friction or resistance through the heater and air ways. The pressure referred to in connection with a fan is that in the discharge outlet, and represents the force which drives the air through the ducts and flues. The greater the pressure with a given resistance in the pipes the greater will be the volume of air delivered, and the greater the resistance, the greater the pressure required to deliver a given quantity.

Fan wheels of the same manufacture are usually made with a constant ratio between the diameter and width, although special forms are made where this does not hold true. All practical data on the action of fans is based on the results of tests, and from these the following relations have been found to be approximately correct.

(1) The volume of air delivered varies directly as the speed of the fan, that is, doubling the number of revolutions doubles the volume of air delivered.

(2) The pressure varies as the square of the speed, for example, if the speed is doubled the pressure is increased $2 \times 2 = 4$ times.

(3) The power required to run the fan varies as the cube of the speed; again, if the speed is doubled the power required is increased $2 \times 2 \times 2 = 8$ times.

The value of a knowledge of these relations may be illustrated by the following example: Suppose for any reason it was desired to double the volume of air delivered by a certain fan. At first thought the decision might be made to use the same fan and run it twice as fast; but when the power required came to be considered it would be found that this would have to be increased 8 times, and it would probably be much cheaper in the long run to put in a larger fan and run it at lower speed. In speaking of a fan as a 4 or 5-ft. fan, the diameter of the propeller wheel is meant, but if an 80 or 100-in. fan is mentioned the height of casing in inches is meant.

It has been found in practice that fans of the blower type having curved floats operate quietly and give good results when run at a speed corresponding to ½ ounce pressure at the discharge outlet; this gives a speed of about 3,600 ft. per minute at the circumference of the wheel. Higher speeds are accompanied with a greater expenditure of power and are likely to produce a roaring noise or cause vibration. A much lower speed does not provide sufficient pressure to give proper control of the air distribution during strong winds. Table 1 gives average capacities for various sizes of fans and the corresponding horse-power of engine required. If an electric motor is used, multiply the horse-power given in the table by 1.3.

TABLE 1.—AVERAGE CAPACITIES FOR VARIOUS SIZES OF FANS AND HORSE-POWER REQUIRED.

Nominal size of fan, height of housing in inches.	Dia. of fan wheel, in.	Width of housing, in.	Ordinary speed giving ½ ounce pressure.	Cu. ft. of air delivered per min.	H.P. of engine to drive the fan.
30	18	9	870	1000	½
40	24	12	580	1600	1
50	30	15	465	2600	1
60	36	18	390	4500	2
70	42	21	333	6000	2½
80	48	24	293	8000	2½
90	54	28	260	11000	4
100	60	32	233	12500	4
120	72	43	195	21500	7
140	84	48	167	28600	9
160	96	48	147	31800	10
	108	54	130	40400	13
	120	60	117	51000	16

This is done because it is impossible to tell exactly what the power required will be, and it is well to have an excess to meet any emergency or unlooked-for conditions which may arise. In the case of a steam engine the steam pressure may be raised to meet any special requirements but a motor can only give out the original power for which it was designed.

A simple, quiet running engine is desirable for use in connection with a fan or blower. It may be either horizontal or vertical and for school-house and similar work should be provided with large cylinders so that the required power may be developed without carrying a boiler pressure much above 30 lb. In some cases cylinders of such size are used that a boiler pressure of 12 or 15 lb. is sufficient. The quantity of steam which an engine consumes is of minor importance, as the exhaust can be turned into the coils and used for heating purposes. If space allows, the engine should always be belted to the fan. Where it is direct-connected, there is likely to be trouble from noise, as any slight looseness or pounding in the engine will be communicated to the air ducts and the sound will be carried to the rooms above.

Electric motors are especially adapted for use in connection with fans. They are easily controlled by a switch and starting box or regulator. The motor may be directly connected to the fan shaft or it may be belted.

With the blower type of fan the size of the main ducts may be based on a velocity of from 1,000 to 1,200 ft. per minute, and the branches on a velocity of 800 to 1,000 ft. per minute, and as low as 600 to 800 when the pipes are small. The velocity in the vertical flues may be from 600 to 700 ft. per minute, although the lower velocity is preferable. The size of the inlet registers should be such that the velocity of the entering air will not exceed 350 to 400 ft. per minute. The velocity between the cold-air inlet windows and the heater may be from 800 to 1,000 ft., provided the distance is short.

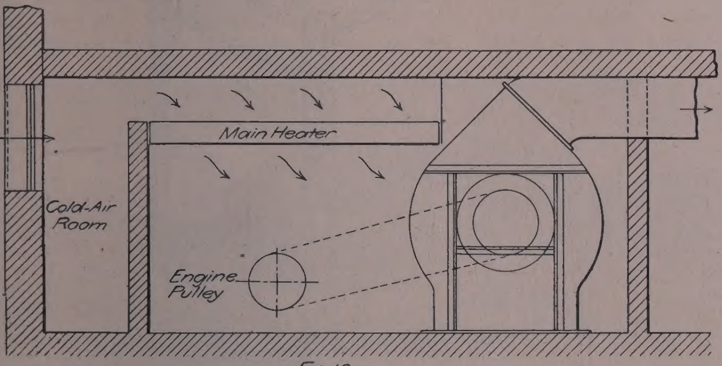


Fig 10

Arrangement of Fans and Overhead Cast-Iron Heater.

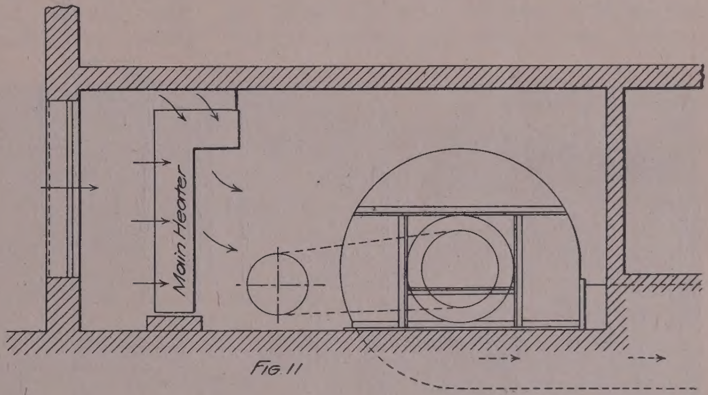


Fig 11

Fan Discharging into Underground Air Way.

When the air is delivered through a register at the high velocities mentioned, some means must be provided for diffusing the entering current in order to prevent disagreeable draughts. This is usually accomplished by the use of deflecting blades of galvanized iron set in a vertical position and at varying angles so that the air is thrown toward each side as it isues from the register. The proper angle for the blades depends upon the position of the register, whether in the corner of a room or in a central position.

The size of the vent-flues should be about the same as for a gravity system, that is, about 6 sq. ft. for a standard class-room, and in the same proportion for smaller rooms. In some buildings large vent-flues are used, extending from the basement through the roof and being connected with two or more rooms on each floor. In cases of this kind the cold air at night is apt to settle down the flue, even though a damper is provided, and flow into the rooms. To prevent this, light checks of gossamer cloth about 5 in. in width are strung on wires and fastened to the backs of the vent grilles. The pressure in the room made by the fan when running will cause the checks to open outward and allow the air to pass by them, but a reversal of the current will close them tightly and prevent the inleakage of cold air. An arrangement of this kind is shown in Fig. 8.

Vent-flue heaters are not usually required in connection with a fan system, as the force of the fan is sufficient to supply the required quantity of air at all times without the aspirating effect of the vent-flues.

The usual form of heating coil as made by the manufacturers of blowers is better adapted to hot-blast heating where high temperatures of air are required than to school-house ventilation which calls for large volumes at moderate temperatures.

A heater for ventilating purposes does not have to be more than 8 to 10 pipes deep, so, if this type is employed, the larger sections may be used and a sufficient number placed side by side to make up the required amount of radiating-surface for a heater of this depth. The form shown in Fig. 9 is particularly adapted to buildings where a large volume of air is to be supplied, and the space available for the heating apparatus is somewhat limited. Heaters of this form may be counted upon to give off at least 1,800 thermal units per hour, per square foot of surface, with a steam pressure of 10 lb. and the entering air at zero.

Cast-iron pin radiators have an efficiency of about 1,500 thermal units under the same condition.

In designing a system of ventilation for a school building the main heater is usually made large enough to raise the total air-supply to a temperature of about 75° Fahr. in the coldest weather. The heat for warming is then provided by a separate system of direct radiation placed in the rooms or by indirect stacks at the base of the flues.

Fig. 10 shows a typical arrangement of fan and overhead cast-iron heater. The air is drawn through the inlet windows, as shown, and passes into the space above the heater; it is then drawn through it and into the fan, from which it is discharged into the main distributing-ducts at the basement ceiling. The bottom of the heater should be at least 30 in. above the water-line of the boiler so that the condensation will easily flow back by gravity through a check-valve.

This is one of the simplest arrangements of fan and heater, as it does away with the use of pumps and traps for returning the condensation to the boiler. When the system is used, an engine with a large cylinder should be employed so that the steam-pressure need not exceed 15 or 18 lb., and the whole system, including the direct surface, may be run upon the same pressure. This arrangement is adapted to all buildings of small and medium size where the heater can be placed at a sufficient height above the boilers.

For large high schools the cast-iron heater becomes somewhat cumbersome on account of its size, and an exceedingly large engine would be required for running the fan on a low steam pressure. In this case it is best to carry a boiler pressure of 35 or 40 lb., and reduce to about 10 lb. for the main heater, and 3 to 5 lb. for the supplementary or direct radiation. The main heater is usually made of wrought-iron pipe in the case of large buildings, being more compact for a given heating surface and thus occupying less space.

Fig. 11 shows a typical arrangement for a pipe heater, with a fan discharging into an underground air-way. As heaters of this type are made to rest upon foundations near the floor, the lower portion is below the water-line of the boilers, and it becomes necessary to return the condensation by the use of a pump or return trap.

The pumps used for returning the condensation to the boilers are automatic in action. They are usually combined with a receiving tank of wrought or cast-iron mounted upon the same foundation.

In buildings of considerable size it is customary to use a wrought-iron tank somewhat larger than that commonly furnished for this purpose, and to connect it with two duplex pumps, each of sufficient size to do the whole work. This gives an extra pump in case of repairs. In this arrangement it is usual to use a pump-governor instead of a float in the tank.

When two pumps are provided it is customary to use them alternately, changing once a week or so, and thus keeping them both in working order. If one is allowed to remain idle too long at one time, it is apt to become rusty or gummed with oil inside.

Where different parts of the system are run on different pressures, it is necessary to discharge the condensation from each into the receiving-tank through a trap; the tank being connected with atmospheric pressure through a vapor pipe carried to the top of the building. Overhead returns and the condensation from the main heater are trapped directly into the receiver, while, in case of the main heating system, it is desirable to seal the long horizontal return pipes in order to ensure quietness of operation. This is accomplished by establishing a "false water-line" at such a height as desired by the use of a "water-line" trap. Fig. 12 shows a common arrangement for the return connections in a combination system of this kind.

The traps for draining the different systems discharge into a vented receiver, as shown, and the water is pumped back to the boilers automatically. A water-level or seal of suitable height is maintained in the returns from the direct heating system by the use of a water-line trap placed at the desired elevation. Part of the sections of the main heater should be valved fo rtaking either exhaust or live steam, and a back pressure valve opening at about 5 lb. should be placed in the outboard exhaust pipe, as shown. This acts as a relief, and opens when the pressure in the exhaust sections rises above the point at which it is set. In case it is desired to run the fan in mild weather when no heat is required, the back-pressure valve should be fastened open and all of the steam exhausted outboard.

In case indirect supplementary heaters are placed at the base of the flues, instead of direct radiation being used, the heating surface may be reduced about one-half.

This is because the higher velocity of the air passing over the heaters when placed in this position doubles their efficiency. Heaters of wrought-iron pipe are sometimes placed in the flues, but more commonly pin-radiators are hung at the basement ceiling and encased in galvanized iron.

Temperature regulation may be obtained by placing mixing or by-pass dampers at the heaters, or by the use of automatic steam and return valves, which shut off and turn on the heaters as required.

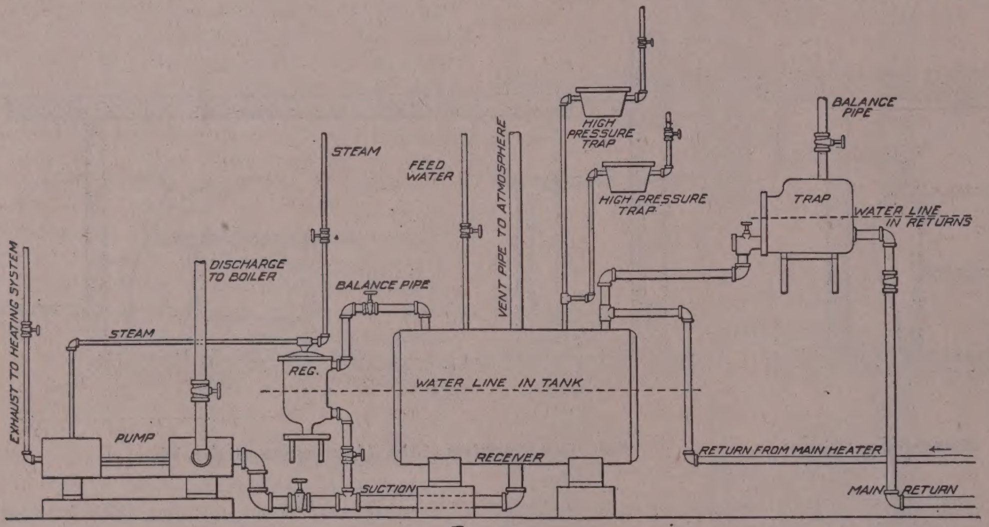


Fig. 12

Arrangement of Return Connections.

In all cases where a fan is used for ventilation, a dial thermometer of large size or a special bulb thermometer with magnifying prism should be connected into the main duct at a convenient point near the fan for indicating the temperature of the air being sent to the rooms.

The ventilation of the toilet rooms of a school building is a matter of the greatest importance. The first requirement is that the air movement shall be into these rooms from the corridors instead of outward. To obtain this result it is necessary to produce a slight vacuum within, and this cannot well be done if fresh air is forced into them. One of the most satisfactory arrangements is to provide exhaust ventilation only, and to remove the greater part of the air through local vents connecting with the fixtures.

There are different ways of doing this; one being to carry a galvanized-iron duct back of the fixtures, having a sectional area of about 12 sq. in. for each one, and connecting with the local vents by short branches. Sometimes a closed chamber is constructed of slate or marble back of the fixtures and the local vents connected directly with it. Ducts are taken from the tops of these chambers and connected with heated flues or with exhaust fans.

In the case of grammar schools or small high schools a loop of 2-in. pipe from 30 to 40 ft. high within the flue will usually furnish sufficient heat to produce the necessary draft. Where it is convenient, a heater of open construction containing 30 or 40 sq. ft. of heating surface and placed in the flue just above the connection from the fixtures will be found somewhat more effective.

In large buildings an exhaust fan is usually connected with the sanitary fixtures. When this is done, a discharge of 10 to 12 cu. ft. of air per minute per fixture should be provided for, which gives a velocity of 125 to 150 ft. per minute through a pipe 4 in. in diameter, and is sufficient to carry off all odors and also provide sufficient ventilation from the room. Disc fans are generally employed for this purpose although steel plate exhausters are advisable if the flues are long or restricted in area.

Small toilet-rooms having a single fixture may be ventilated entirely through the local vent, the same being connected with a 5 or 6-in. vertical pipe containing a loop of ¾-in. steam pipe 6 or 8 ft. in height. This vent-pipe may be carried up inside the vent-flue from a class or other room to a point 12 or 15 ft. above the last inlet opening from a room, and may then discharge into the general ventilation. When carried to this height there is very little danger of odors being carried downward into the rooms by back-drafts.

Chemical hoods are either connected with a hot flue or are ventilated by means of a fan. Where there are only three or four, a gas jet placed in the top of each, just below the outlet will often give sufficient draft. When there are a larger number of hoods to be ventilated, it is better to connect them with a fan of sufficient capacity to change the entire contents of all the hoods five or six times per minute. A fan for this purpose should be provided with copper blades and the connecting ducts should be either coated with asphaltum or made of tile. Fig. 13 shows a good form of construction for a chemical hood. "A" is the fume closet, provided with a sliding sash in front, which is prevented from closing entirely by a stop "C." "B" is a chamber common to all of the hoods and connects with a flue at the back as shown. The path of the air currents is indicated by the arrows. The bottoms or floors of the fume closets are covered with slate slabs, and each is provided with a cupboard and shelf beneath.

The Tunnel Under Capitol Hill at Washington by which the Pennsylvania R. R. will reach the new Union Station has been completed. This tunnel is 4,033 ft. long and consists of two tubes separated by a masonry wall, each tube carrying a single track. Through this tunnel trains to and from the south will secure direct communication with the new terminal station.

Compressed Air Locomotives.

Compressed air locomotives are used in handling the 11,700 tons of ore, limestone, coke and coal brought daily to the Washoe plant of the Anaconda Copper Mining Co. Counting rehandled materials twice, more than 13,000 tons are handled about the works by means of thirteen compressed-air locomotives, twelve weighing 13 tons each, and one, 21 tons. Each locomotive carries two storage-tanks for its air-supply, the air being taken from a pressure-system of pipes laid conveniently to the tracks, and having stations at which the locomotive stops to get its air-supply. This supply is carried at from 800 to 900 lb. per square inch. A reducing-valve between the storage-tanks and the cylinder reduces the pressure to 150 lb. A fresh supply of air is taken at times ranging from twenty to sixty minutes. For this particular service, where the distances run are short, and where the cars are frequently stopped and started, the compressed-air locomotives have been most satisfactory, for convenience, reliability and simplicity of operation. They have been in constant service since 1900, and have needed only the natural running-repairs. They are operated over tracks aggregating 48 miles in length, which are distributed over the side-hill location of the works about half a mile square. The present locomotives have been able to stand the hardest and roughest usage with but little injury. Under like conditions, it is believed that electric locomotives would have had coils burned out, short-circuiting and other troubles.

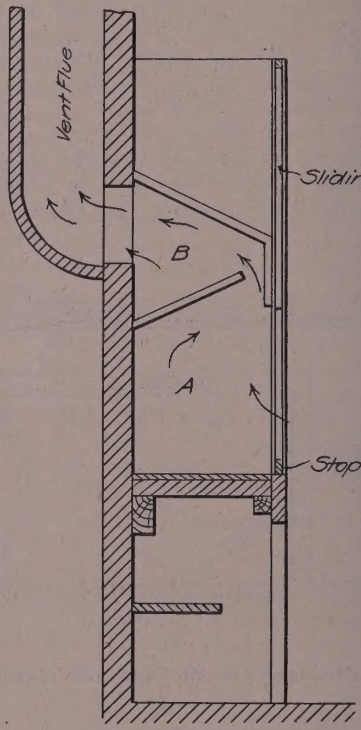


Fig. 13

Connections for Chemical Hoods.

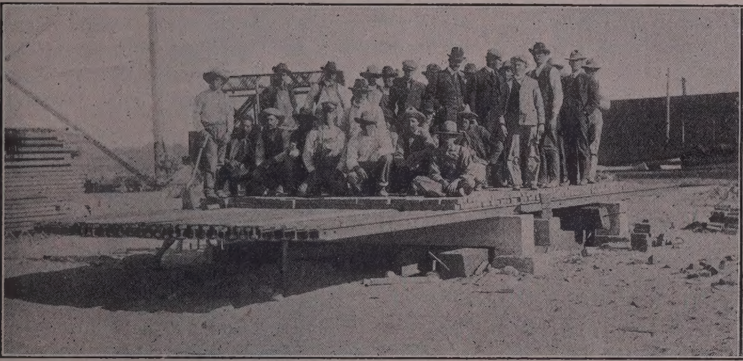
Storing Coal in Pits capable of being flooded has been adopted at the new plant of the Western Electric Co., at Hawthorne, Ill. A plot about 320 x 75 ft. has been excavated to a depth of about 12 ft., and lined and sub-divided by concrete walls into twelve 80x25-ft. pits. Their bottom is the clay sub-soil and the walls are carried about 4 ft. above ground. The pits can be flooded by means of a 12-in. water main. The longitudinal division walls are wide enough to carry the tracks on which the coal is delivered. It is removed from the pits by a steam shovel.

Letters to the Editor.

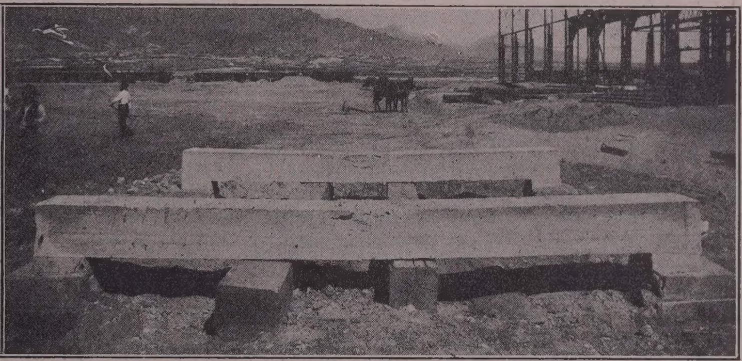
THE THEORY OF FLEXURE OF REINFORCED CONCRETE.

SIR: The writer was interested and pleased in reading your discussion of the theory of flexure of reinforced concrete, appearing on page 281 of your issue of Sept. 15. In the rather voluminous current literature on reinforced-concrete beams appearing during the past year or two in the technical journals, it appears to the writer that there has been quite a lot of refined assumptions and theories interjected into the subject which have added little or nothing to the value of the discussion from the practical standpoint of a man who is under the necessity of designing and building reinforced-concrete beams that will stand up safely under required loads without being unnecessarily expensive in the use of material.

To those who have been engaged in this latter work, and charged with its responsibilities, it is quite evident that the hair-splitting about the precise, probable or possible position of the neutral axis under initial and final loads, and whether or not the stresses in the compression side of the beams are properly expressed by the straight line or the parabola, sink into insignificance as compared with the quality of the concrete materials, their proportions, the care with which they are worked into the beam, and the excellence or inferiority in the quality of the resulting concrete. Also that the necessary assumptions as to permissible maximum stress in the extreme fiber, and the resulting mean pressure in the concrete under compression, affect the safety of the beam under load much more directly and materially than the widest variations in the opinions of the experts relative to the refined theoretical assumptions above mentioned.



Load on Beams.



Beams After Test.

The writer submits, as safe and economical, the following formulas for practical work, for reinforced-concrete beams when the width is fixed:

Let w = width of beam,
d = depth from top of beam to center of steel,
$\frac{1}{2}d$ = position of neutral axis above center of steel,
$\frac{5}{6}d$ = position of center of pressure above center of steel,
p = mean pressure per square inch in concrete above neutral axis,
t = tension per square inch in steel,
p/t = percentage of area of steel in terms of area of concrete in compression.
m = maximum moment of total load.

When width of beam is fixed, then

$$p\ w\ (\tfrac{1}{2}d \times \tfrac{5}{6}d) = m$$

Therefore, $d = \sqrt{(m \div 5/12\ p\ w)}$

Taking maximum compression on extreme fiber of concrete at 504 lb. per square inch, p becomes 336, from which

$$d = \sqrt{(m \div 140\ w)}$$

Taking t = 16,000 lb., p/t becomes 3.36 ÷ 16,000 = 2.1 per cent.

When the depth of beam is fixed, the width may be found as follows:

$$w\ p\ (\tfrac{1}{2}d \times \tfrac{5}{6}d) = m$$

Therefore $w = m \div 5/12d^2\ p$

With $p = 336$, as above, $w = m \div 140d^2$.

It is believed that the assumed positions of the neutral axis and the center of compression in the compression side of the beam as above are well within permissible limits, as indicated by the general average results of almost all experimenters. Certainly any variations in the positions assumed will introduce elements of uncertainty much less than must be taken into consideration in the character and quality of the concrete itself. The assumed positions cannot materially shift within the safe working stresses.

Several hundred reinforced-concrete lintels, which have been constructed over the doors and windows of our machine shops at El Paso, Texas, and varying in spans up to 12 ft., are safe as tested by the foregoing formulas, and as further indicated by the fact that in no case has any of them broken under full working load.

The accompanying photographs are of the test to destruction of lintels similar to those spanning the engine door openings of the machine shop. One of these shows the beams during loading. The men were removed and additional brick added until the beams finally failed by crushing in the center on the compression side, as indicated in the other photograph. The first lintel broke when the total distributed load on both was 68,120 lb. The second lintel broke when the total load on both was 72,180 lb. Just prior to beginning of failure by crushing, the deflection of the first beam was 1⅛ in., and that of the second 1 in. The beams crushed and settled slowly through a period of about 20 seconds until they rested upon the timbers underneath, as indicated in the photograph. These beams were of 12-ft. span, 11½ in. deep from center of the steel reinforcement to the top of the beam, 12 in. wide, and were reinforced against shearing by ¼-in. stirrups.

Taking the mean total distributed load on both beams at the time they began to fail at 70,000 lb., the resulting moment of the load at the center of either beam would be 630,000 in.-lb. In formula No. 1 above, the safe moment would be $m = 140wd^2$

This formula applied to the beams in question would limit the safe load to one producing a maximum moment of 222,180 lb. Consequently, if these beams had been loaded no more than allowed by the formula, they would have a mean factor of safety of 2.87. The concrete in the lintels in question was mixed in the proportion of 1, 2 and 4. For reinforced beams made with different mixtures, the assumed allowed stress in the concrete would, of course, have to be varied accordingly.

The above assumed permissible working stresses per square inch in the concrete have reference, of course, to static loads only.

Yours truly, J. L. CAMPBELL.

EL PASO, TEX., Sept. 21.

MISTAKES IN WATERPROOFING.

SIR: It is a pleasure to read the fair-minded letter on page 251 of your Sept. 1 issue, in reply to certain statements contained in the writer's paper "Mistakes in Waterproofing." Your correspondent, however, has unfortunately passed by one of the principal points in that paper, against the cement plaster method, and we beg to ask that he please answer it. The point, quoted, reads as follows:

"It is against the logic of things to place the waterproofing in front (where in time it can be shoved off) of the line of resistance (the wall) instead of behind it. One of the chief uses of waterpoofing is to keep water entirely from the wall—instead of allowing it to come to and through it—and by capillarity work up and saturate the entire wall, and in the course of years press off the hardened cement (or even paint) coating on the other side, which it must finally do by the very law of nature." Why permit the saturation of the wall?

However, to consider directly the points raised by your correspondent. He begins by saying that "all waterproofing will crack," a very necessary claim in view of his next admission that "cement waterproofing will crack." His first statement, however, cannot be accepted without his first properly proving the cracking of the particular waterproofing method described in the paper to which he replied—because one of the basic principles of that method is elasticity vs. cracking. His having already admitted our claim that the cement will crack, that point is not now in dispute. But he cannot "for the sake of argument" as he expresses it, include in that admission as to his own material "all" waterproofing, because the point is too vital, it happening to be the basis on which rests his entire argument. Having assumed, therefore, "for the sake of argument," a wrong premise, he must also assume the naturally wrong conclusion.

We beg to bring your correspondent back to the real question at issue, which is, not all waterproofing, but the "membrane method" vs. the cement (plaster) method. The basic principles of the two methods are as divergent as the poles. There is plenty of room for interesting and profitable discussion without over-reaching or assuming an erroneous premise simply for convenience or "for the sake of argument." Each method rests on its own basis—and it should be a fairly easy matter to decide between the essential features of each. In one, the principle is elasticity, and in the other rigidity; in one, independence of the surface or structure, and in the other an integral part thereof. One yields to settlement and contraction and expansion; the other cannot do so and cracks.

Nor is it necessary to extend the definition of cracking so as to make it embrace cracks from settlement so great as to bring down the structure, especially when it is also admitted that the cement method depends absolutely upon the immovability of the structure or surface to which it is applied. No better evidence of this fact can be had than is furnished in the words of the guarantee quoted by your correspondent and which reads as follows: That the cement used "will fulfill its purposes as a waterproofing agent so long as the material on which it is placed remains in a sound and stable condition." Your correspondent further says, "This claim can have but one interpretation; a guarantee that contractors will be responsible for the material so long as the structure stands."

This interpretation is very wide of the words as nominated in the guarantee. There is a great deal of difference between a structure standing and its remaining "sound and stable." A guarantee under such conditions is the safest thing possible for the guarantor—hence so readily given. The writer has always contended that a foundation waterproofing guarantee is practically worthless. There is abundant experience and evidence (aside from that furnished by the above mentioned guarantee) to this effect. A roofing guarantee, on the other hand, is of considerable value because the conditions are entirely different. On close analysis it would be seen that the above quoted "guarantee" really guarantees nothing—except that the cement will crack and that it will not yield to natural settlement of the wall, contraction and expansion, to the jar or shock of heavy machinery, street traffic, blasting, etc. We do not refer to the old school process of using tar and tar paper. Of what use is a waterproofing which will not accommodate itself to the wall, instead of having the wall accommodate itself to the waterproofing (i. e., of having the owner guarantee that his wall will not crack your waterproofing). Waterproofing is applied to protect the surface waterproofed under all conditions—settlement, jars, shocks, expansion, contraction, heat, cold, water, snow, ice, etc. To accommodate itself to and protect the wall or other surface under above described conditions is exactly what the elastic "membrane method" does, and what the rigid cement method, by its own guarantee, does not and cannot do. It matters not then how durable may be the cement.

Further, in addition to the undesirability, on general principles, of permitting water to soak through the entire wall and gradually work its way upward, the presence of moisture or water in the wall constantly pressing against the thin layer of cement plaster on its inner surface is to make the entire wall, including the cement coating, so cool or cold as to make it difficult if not impossible to heat the wall and prevent condensation thereon. As it will be also practically impossible to drive the moisture out of the wall, the condition will grow more serious with time. As furnaces and boilers are placed in the foundation and heat draws waters, instead of driving the water out of the wall it will tend to draw it through it. All this aside from any consideration of the cracking of the cement itself. On the other hand, the "membrane method" not only insulates the wall against the surrounding earth, but keeps the water entirely away from and out of the wall, making a dry wall susceptible of heat or warmth and preventing condensation thereon.

No one will deny that the saving of space by placing a waterproofing on the inner surface of foundation walls is a desirable thing, but the value of the space saved is infinitesimal compared to the healthfulness and safety of the very foundation of the structure itself, by the use of a logical, natural method of waterproofing which will prevent the saturation and constant wet condition of the entire walls.

Your correspondent's point with reference to the word "patch" is illogical because of a misconstruction of the term. The writer used it in its right sense, meaning to repair; not fabrication as your correspondent uses it. Fabricating the various strands into a rope is, for instance, not repairing. He admits, however, that while "patching is not perfection," that "with cement it is possible to make a perfect patch."

His final point that "it is only fair to state that there is but one cement that is a positive waterproofing agent" is one of his strongest arguments in favor of the "membrane method." As there are quite a number of cements on the market, his agreeing with us that none of them are of any waterproofing value excepting one, is exceedingly strong evidence in support of our argument against the cement method generally, and would practically prove 99 per cent. of our case.

The writer in his paper stated that cement waterproofing could not be used on a roof. Your correspondent says in reply, "We are also told that cement waterproofing cannot be used on a roof, whereas, at this very time the roof of the White House at Washington is being so waterproofed." This seems misleading. The writer was authoritatively informed that the contract for the roofing for the East and West Terraces at the White House called for a waterproof fabric or felt, and over it a certain cement plaster. The writer when recently in Washington and at the White House terrace work saw this fabric, which is a grit-covered prepared roofing made by a New York State roofing manufacturer. This roofing being in place, over it was applied, as a wearing or walking surface, the cement "waterproofing." If the cement per se were sufficient for waterproofing the terraces, why was it not used alone? Why was it first necessary to waterproof the roof with a roofing, if it were not for the admitted fact that the cement plaster would crack, especially under the severe temperature and weather changes to which it would be exposed—thus making it, precisely as the writer claimed, unsuited in itself for roofing? Do these facts not also greatly tend to prove the lack of waterproofness, under general conditions, of the cement method. It is unfortunate that your correspondent should have made the statement he did regarding the roof of the White House without mentioning the use of the felt roofing under the cement. We think your correspondent should have an opportunity to correct his original statement.

Very truly yours, Edw. W. De Knight.

New York, Sept. 15.

Sir: Just at this season we are so busy applying cement waterproofing that we have but limited time to write theoretical discussions upon the subject. Our answer, therefore, to the letter printed above is not as full as so brilliant a literary achievement warrants. But time at least must be found in which to answer the "principal point," which we are told was so unfortunately passed by in the writer's former letter, "why permit the saturation of the wall?" It is an admitted fact among engineers that brick, stone, or concrete masonry properly constructed of sound materials and with cement mortar will not disintegrate nor deteriorate if submerged in water. In fact, many authorities hold that concrete is materially benefited by being constantly wet. If, then, remaining in a wet condition does no injury to the wall, why go to infinite pains and expense to keep it dry throughout? So long as water does not come through the wall, and there is not the slightest evidence of dampness upon the inner surface, nothing more is necessary. It should be borne in mind that by the cement process the cost of furring and of the finished plaster surface is saved, and that valuable space is acquired in the basement, which in a short time will in rentals equal the entire cost of the waterproofing. So far from being "logical," it would seem a useless proceeding to place waterproofing in a way which interferes with the general progress of construction, in a position where it can never be reached again, and where either costly excavation must be done or space sacrificed.

As for capillary attraction, which seems such a menace to your correspondent, in few walls have we seen dampness extend beyond 24 in. above grade. It has not been our misfortune to find a single instance where by "capillary attraction the water has worked up and saturated the entire wall." If, however, it ever becomes the practice to build walls of such porous or absorbent material that this phenomenon should take place, it would be a most simple and economical proceeding to return the cement waterproofing through the wall from the inner surface to the outer, at or slightly above grade, thus checking absolutely this creeping tendency, which seems to be regarded with such dread.

Your correspondent states that cement "will not yield to natural settlement of the wall." Until he explains to us his definition of "natural settlement," and how such differs from unnatural settlement, we cannot answer the point. But we cheerfully admit that if his "membrane method" will, as he states, under all conditions of settlement, jars, shocks, etc., remain intact, he has solved a great problem. But perhaps we are interpreting too literally, and that he means "natural" settlement, "natural" jars, "natural" shocks, etc.

As for heat, cold, water, snow and ice, cement will stand as much of these as will any paper, felt, pitch, asphalt or other material we have seen used as a waterproof agent. As a matter of actual experience we have encountered no expansion nor contraction below grade which is sufficient to cause trouble to cement waterproofing. And when the jar or shock from machinery begins to do so, it would appear that the mechanical engineer had better look to the arrangement of his plant to remedy the evil before his appliances are racked to pieces.

Regarding condensation, we must again call upon actual experience as against theory. We have found that walls waterproofed upon inner surfaces with cement are no more subject to this cause of dampness than those waterproofed upon outer surfaces. Where proper ventilation exists no condensation is found upon any walls waterproofed with cement.

As for the roofs of the White House terraces, the writer was not aware that any fabric or felt was used in this work. But he does not credit the statement that the Hydrolithic cement is used solely as a wearing surface. If this is to act simply as a pavement, why go to the unnecessary expense of employing a cement which in cost is about double that of ordinary Portland, with which can be produced the very best granolithic finish. For an answer to these last questions we refer your correspondent to the Chicago firm which is doing the work at the White House, and which we believe will be glad to have an opportunity to answer.

Fred'k S. Greene.

Sands Point, N. Y., Sept. 30.

Forestry Work is now done by fourteen States, six of which employ technically trained foresters. The State of Washington has made provision for both a forest commission and a forester, and Maryland has enacted a law providing for a forester and granting power to purchase lands suitable for forest reserves.